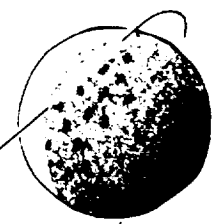


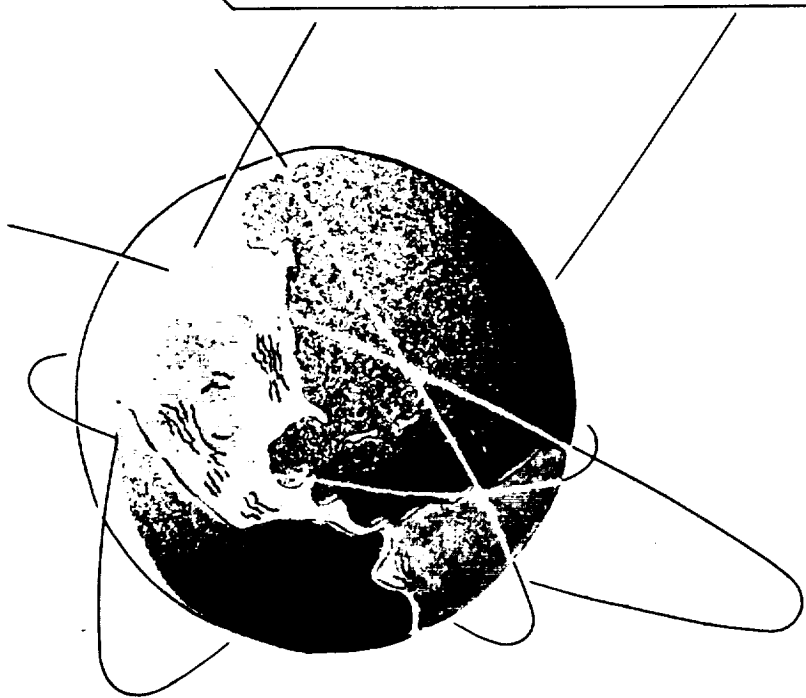
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p. 59



**PRECISION GPS EPHEMERIDES
AND BASELINES**

**Final Report for NASA Grant No. NAGW-2717
January 1991 - December 1991**



CENTER FOR SPACE RESEARCH

THE UNIVERSITY OF TEXAS AT AUSTIN AUSTIN, TEXAS

(NASA-CR-190247) **PRECISION GPS EPHEMERIDES
AND BASELINES Final Report, 1 Jan. - 31 Dec.
1991 (Texas Univ.) 59 p** **CSCL 17G**

N92-23541

**Unclas
G3/04 0085179**

PRECISION GPS EPHEMERIDES AND BASELINES
NASA GRANT NO. NAGW-2717

Final Report
January 1, 1991 – December 31, 1991

INTRODUCTION

The emphasis of this grant was focused on precision ephemerides for the Global Positioning System (GPS) satellites for geodynamics applications. During the period of this grant, major activities were in the areas of thermal force modeling, numerical integration accuracy improvement for eclipsing satellites, analysis of GIG '91 campaign data and the Southwest Pacific campaign data analysis.

THERMAL FORCE AND ECLIPSING ORBITS

Papers on thermal imbalance force modeling and eclipsing orbit analysis were presented at the AIAA Space Flight Mechanics Conference held in February 1992 at Houston, Texas. Details are included in Appendix VII and Appendix VIII of the Final Report for NASA Grant No. NAG5-940.

GIG '91 DATA ANALYSIS

An intensive global GPS observation campaign called "The First GPS IERS and Geodynamics Experiment – GIG '91" was organized by the Jet Propulsion Laboratory for a period of three weeks during early 1992. The campaign spanned part of GPS Weeks 576, 577, 578 and part of Week 579 starting from January 22, 1992, to February 13, 1992. About 120 stations distributed globally, collected data during this period using a variety of GPS receivers which included Rogues, TI-4100's, Trimbles, Ashtechs, Mini Mac 2816 AT's, WM-102's; in addition, data from the five continuously operating DMA stations were also available. From among these, data from 20 globally distributed stations were chosen for orbit determination and Earth orientation parameter determination experiments at UT/CSR. Of these, 17 sites had Rogue receivers, two TI-4100 and one Mini Mac

2816AT. Orbit determination experiments included computation of orbits using data from a reduced set of global stations and from an expanded set, and comparing the baselines and other criteria to assess the orbit accuracy. In addition to the GIG'91 data set mentioned above, data collected during the 1989 South West Pacific Campaign also were used. Results of this study were presented at the 1991 AGU Spring Meeting held at Baltimore, Maryland, during May 1991. Further details are included in the Appendix.

Using the same GIG'91 data set several experiments were performed at CSR to determine the pole positions (X_p , Y_p) during this time period. The main objective of the experiments was to explore strategies for determining the Earth orientation parameters (EOP), polar motion and UT1, using global GPS data. Short arc and long arc with sub arc parameters were considered as possible approaches. The estimated pole positions were compared with SLR and VLBI determined polar motion series in order to assess the quality of these determinations. Results of this study were presented in the special workshop held in Ahrweiler, Germany, during August 1991 and at the XX General Assembly of the IUGG during August 1991 in Vienna, Austria. A copy of the presentation is included in the Appendix.

SWP CAMPAIGN DATA ANALYSIS

Analysis of data collected during the South West Pacific (SWP) campaigns contributed to accuracy assessment of the GPS satellite orbits. The SWP campaign data were collected during the summers of 1988, 1989 and 1990 and these data have been analyzed in various stages at CSR. These data sets complement the CIGNET data in forming a better global distribution and facilitates various orbit and baseline experiments. Studying the repeatability of baselines between various sites in the SWP network provides one method to evaluate the accuracy level of the computed orbits. In depth analysis of few weeks of data collected at the sites in Tonga region (SWP) during the above three years were performed at CSR and the results indicate that the computed GPS orbits yield baseline

repeatability at the 10 to 20 parts per billion (ppb) level. A brief summary of these results were presented at the 1991 AGU Fall Meeting held in San Francisco during December 1991. Copy of the presentation is included in Appendix.

CONCLUSION

Based on the research efforts at CSR in the area of precise ephemerides for GPS satellites, the following observations can be made pertaining to the status and future work needed regarding orbit accuracy. There are several aspects which need to be addressed in discussing determination of precise orbits, such as force models, kinematic models, measurement models, data reduction/estimation methods etc. Although each one of these aspects has been studied at CSR in research efforts under this (and the previous) grant, only points pertaining to the force modeling aspect are addressed here.

Dynamic Modeling – Current Status

At present the following known forces are modeled in routine computation of GPS satellite orbits:

(1) Nonspherical Earth gravity acceleration represented by one of the extant gravity fields such as GEM-L2, GEM-T1 or GEM-T2 truncated to 8×8 is adequate. However, increasing the degree and order and/or tuning the field (at least the resonance coefficients) for GPS orbits may slightly improve the accuracy of this perturbation modeling.

(2) represented as point masses are adequate.

(3) force modeling and the geometric tide effects must be considered in the measurement models.

(4) Perturbation due to solar radiation pressure is adequately modeled by the ROCK4 models; however, it is necessary to scale these accelerations by at least one adjustable parameter.

(5) Perturbation due to venting of the heat source in the GPS satellite is modeled as 'Y-bias acceleration' scaled by an adjustable parameter.

Values of weekly estimates of this scale parameter considered over a period of time do not exhibit any systematic trend except for a somewhat weak correlation with the eclipsing period. Experience shows that it is necessary to include this perturbation along with an adjustable parameter in order to obtain good fit of the data. However, in a long arc solution, considering several sub arcs for this perturbation does not significantly improve the rms of fit.

Following are some of the factors which could contribute to additional improvement of orbit accuracy beyond the current level.

(1) Perturbation due to imbalance in thermal radiation has been shown to cause differences in orbit prediction at the level of a few meters over a period of about one week or more. Although small, inclusion of this perturbation may help in achieving baseline accuracies (and/or repeatabilities) at parts per billion level. But the difficulty in considering this perturbation routinely is due to the fact that nonlinear partial differential equations (heat equations) must be solved simultaneously with the ordinary differential equations of motion, which causes significant complications in algorithm and computation even for a modest approximation of the satellite configuration. Hence, careful evaluation of the costs and benefits of including this perturbation is needed.

(2) handling discontinuities in function values (occurring in SRP acceleration at shadow crossings), can be overcome by the ad hoc modification of the integrator back difference table. However, inclusion of this modification did not seem to improve the rms of fit or the prediction error in real data processing, although improvements were obvious in simulation studies. The reason for this anomaly is not known at present and will have to be investigated before this feature can routinely be included in orbit computation.

Dynamic Modeling – Future Study

There are indications (evidenced by discontinuities in daily/weekly solutions and by prediction errors) to the effect that all the perturbations described above do not completely or exactly represent all the forces acting on the GPS satellites. There may be other unmodeled forces such as unintentional thrusting (due to outgassing, momentum dumping, attitude correction etc.) or due to other natural phenomena. One of the ways in which such unknown and unmodeled perturbations could be accounted for in orbit computation is to estimate empirical accelerations. Such an approach needs detailed analysis in the future.

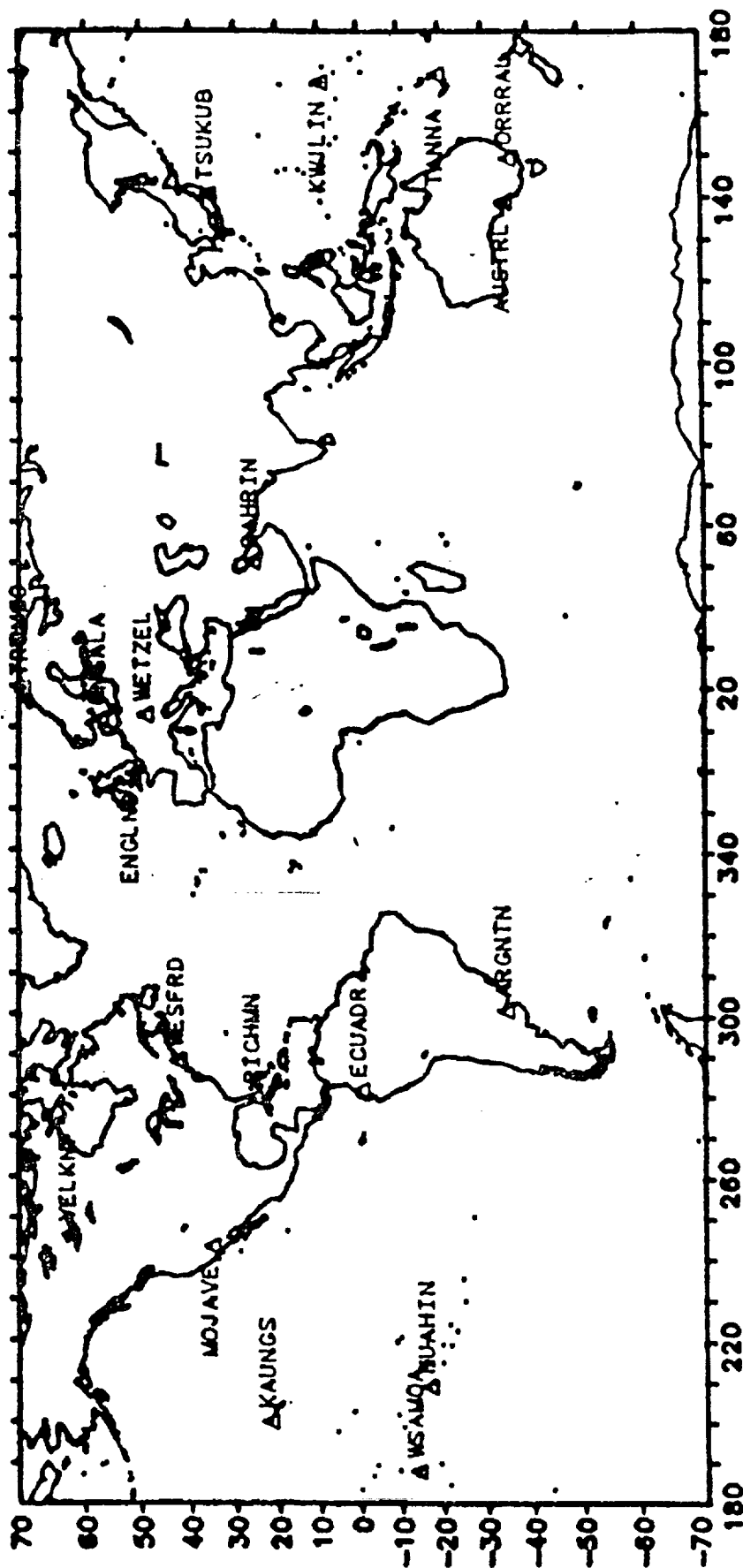
APPENDIX

1. "GPS Ephemeris Accuracy Improvement From Global Data Set," AGU 1991 Spring Meeting, May 28–31, 1991, Baltimore, Maryland.
2. "Analysis of GIG 91," presented at GIG Workshop, Ahrweiler, Germany, August 1991.
3. "Global GPS Orbit Determination," XX General Assembly, IUGG, August 11–24, 1991, Vienna, Austria.
4. "Geodetic Analysis of GPS Measurements Near the Tonga Trench: 1988–1990," AGU 1991 Fall Meeting, December 1991, San Francisco, California.

GPS EPHEMERIS ACCURACY IMPROVEMENT
FROM GLOBAL DATA SET

P.ABUSALI, B.SCHUTZ, B.TAPLEY, D.KUANG
CENTER FOR SPACE RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

AGU 1991 SPRING MEETING
MAY 28 - 31, 1991
BALTIMORE, MARYLAND



LOCATIONS OF STATIONS WHICH OBSERVED DURING S.W. PACIFIC CAMPAIGN
INCLUDING THE FIVE DMA STATIONS (TOTAL 19) ; GPS WEEK-499

GLOBAL TRACKING NETWORK DATA FOR WEEK 499

CIGNET	AUGMENTED	DMA
Mojave, CA (MM)	Orroral, Australia (TI)	Buenos Aires, Argentina (TI)
Westford, MA (MM)	Huahine, Fr.Polynasia (TI)	Quito, Ecuador (TI)
Yellowknife, NWT (TI)	Tanna (TI)	Smithfield, Australia (TI)
Kauai, HI (TI)	Western Samoa (TI)	Hermitage, England (TI)
Wetzell, Germany (MM)	Kwajalein (TI)	Bahrain (TI)
Onsala, Sweden (TI)	Santo (TI)	
Tromso Norway (TI)		
Tsukuba, Japan (MM)		
Richmond, FL (MM)		

SOLUTION CHARACTERISTICS FOR THE GLOBAL DATA SET

	<u>WEEK 499</u>	<u>WEEK 500</u>
NO. OF STATIONS	9	9
NO. OF DD OBSERVATIONS	43294	38189
NO. OF ESTIMATED PARAMETERS	436	373
RMS OF FIT (CM)	2.54	2.66

	<u>WEEK 499</u>	<u>WEEK 500</u>
NO. OF STATIONS	20	19
NO. OF DD OBSERVATIONS	106417	94916
NO. OF ESTIMATED PARAMETERS	1016	906
RMS OF FIT (CM)	2.904	2.877

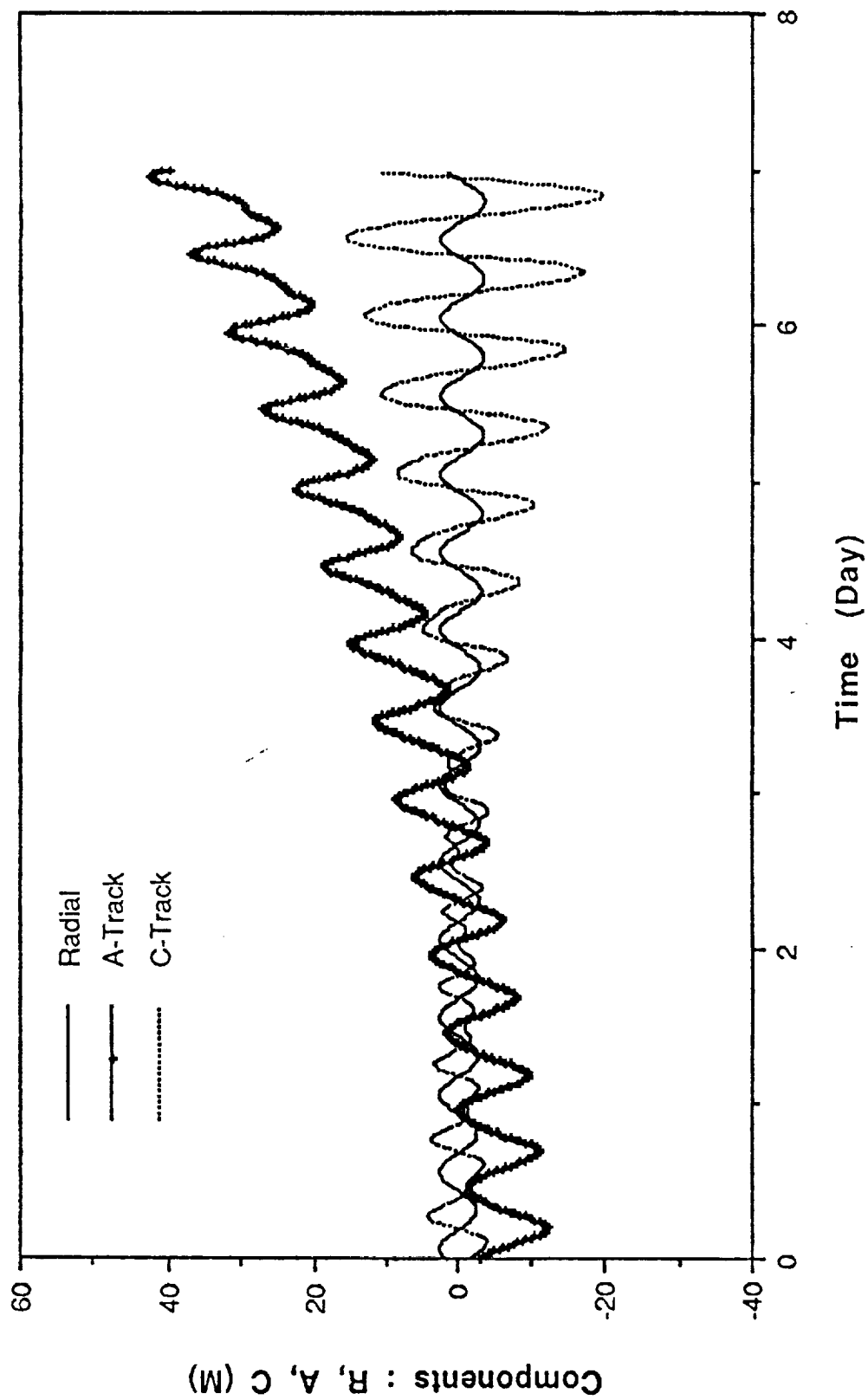
TROMSO-ONSALA VECTOR BASELINE ACCURACY
COMPARISON WITH VLBI SOLUTION

	<u>Week 499</u>			<u>Week 500</u>	
	10 GS	20 GS	10 GS	19 GS	
North (M)	-0.0286	-0.0313	-0.0591	0.0479	
East (M)	-0.0112	-0.0670	-0.0194	0.0229	
Vertical (M)	0.0757	0.0127	0.0668	0.0312	
<hr/>					
Length (M)	-0.022	-0.048	-0.054	-0.042	
	(1.5 x 10-8)	(3.4 x 10-8)	(3.8 x 10-8)	(3.0 x 10-8)	

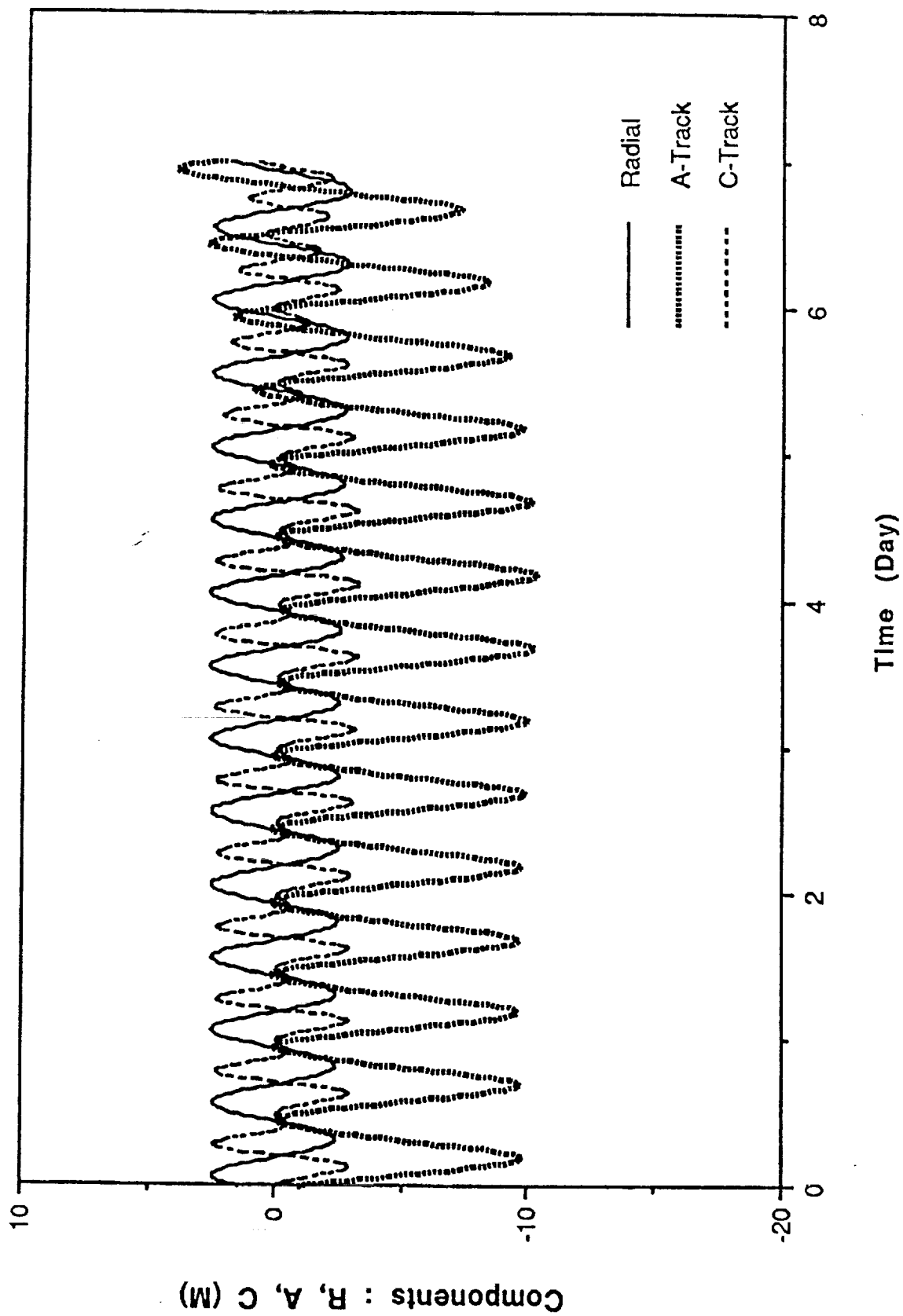
RMS OF TRAJECTORY DIFFERENCES
9 GS vs 20 GS SOLUTIONS

PRN	RADIAL (M)		A-TRACK (M)		C-TRACK (M)	
	9 GS	20 GS	9 GS	20 GS	9 GS	20 GS
3	2.043	1.836	15.571	5.736	6.244	1.571
6	3.011	2.463	60.891	68.912	22.859	26.330
9	2.204	1.931	5.920	8.556	2.017	3.222
11	0.728	1.044	5.104	2.443	1.927	1.094
12	2.312	1.403	30.271	20.761	10.978	8.258
13	2.015	1.657	10.176	15.882	3.923	6.074

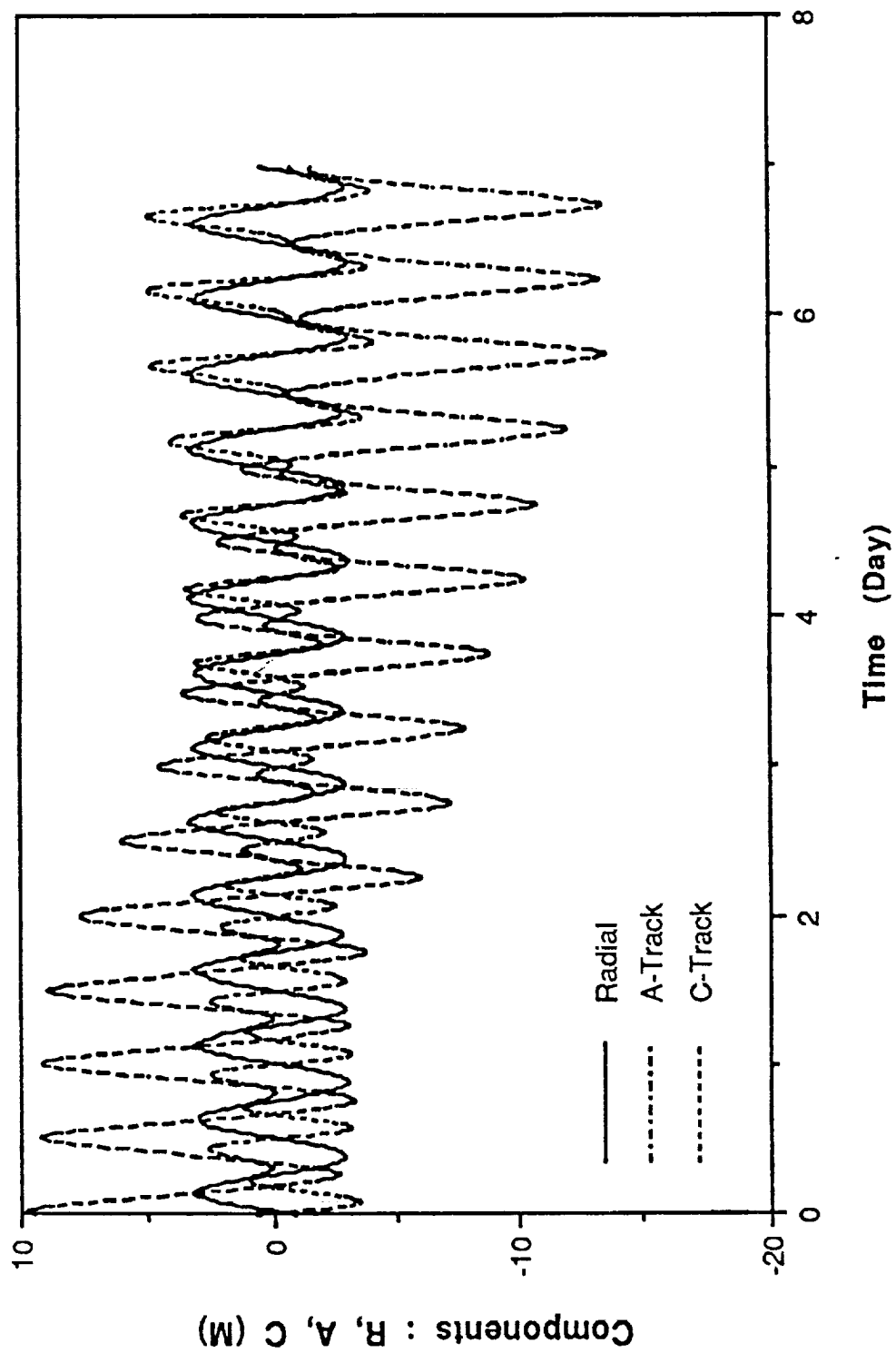
(Pred vs Fit) in W500 for PRN-03
9 Ground Stations



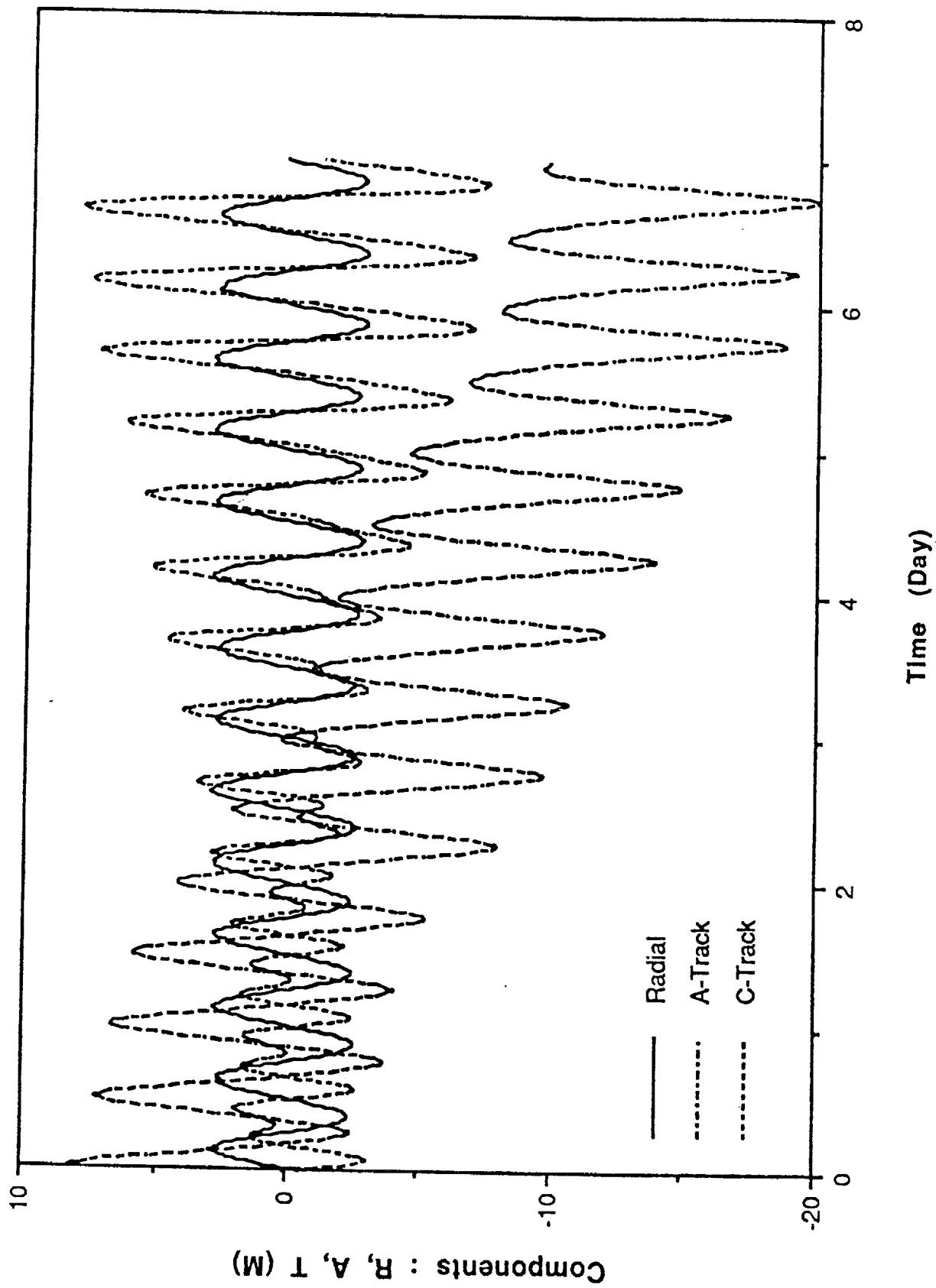
(Pred vs Fit) in W500 for PRN-03
20 Ground Stations



(Pred vs Fit) in W500 for PRN-09
9 Ground Stations



(Pred vs Fit) in W500 for PRN-09
20 Ground Stations

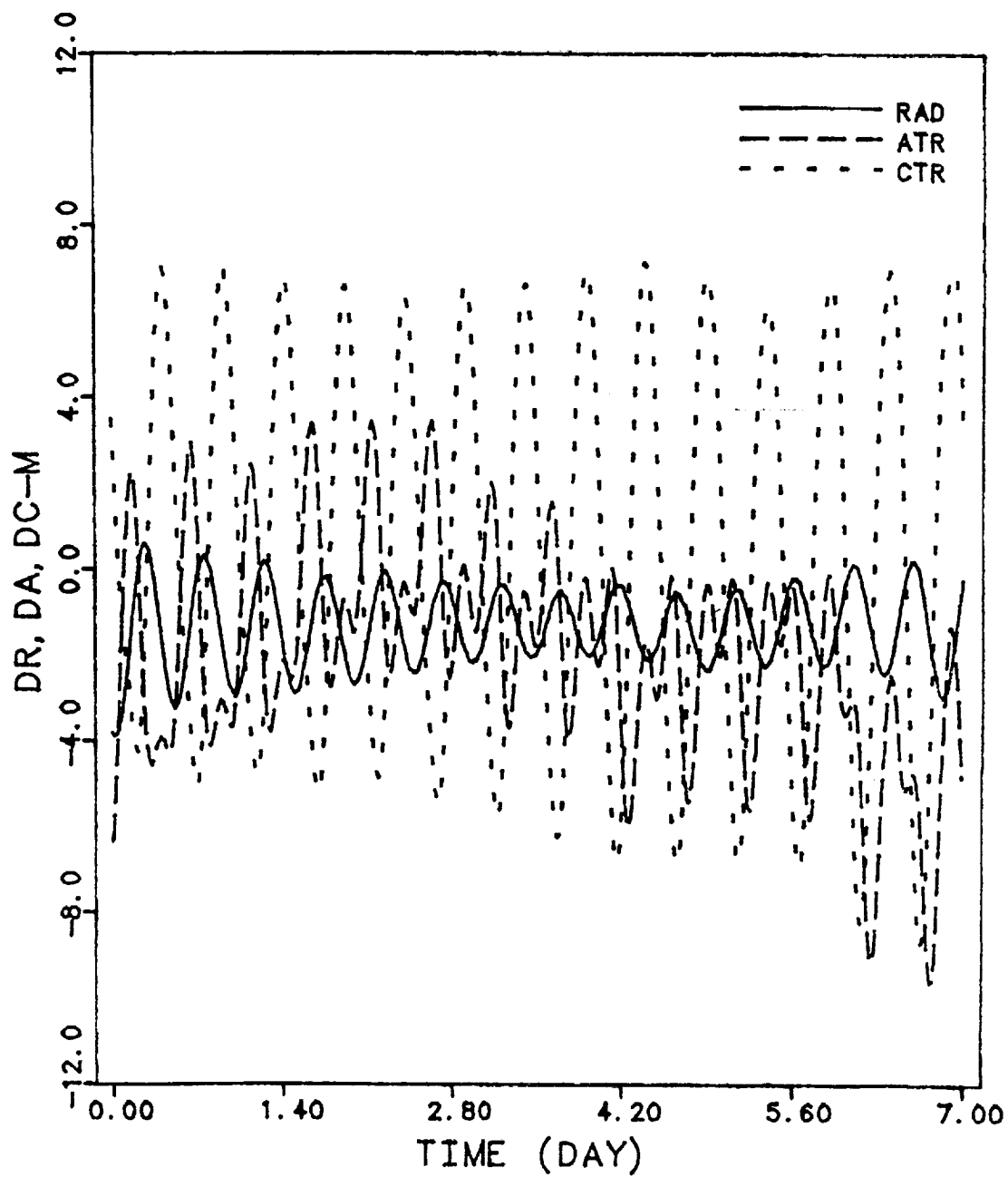


ECF EPH DIFFERENCES (WEEK 499)
(UT/CSR DD PHASE SOLN - NSWCEPH)

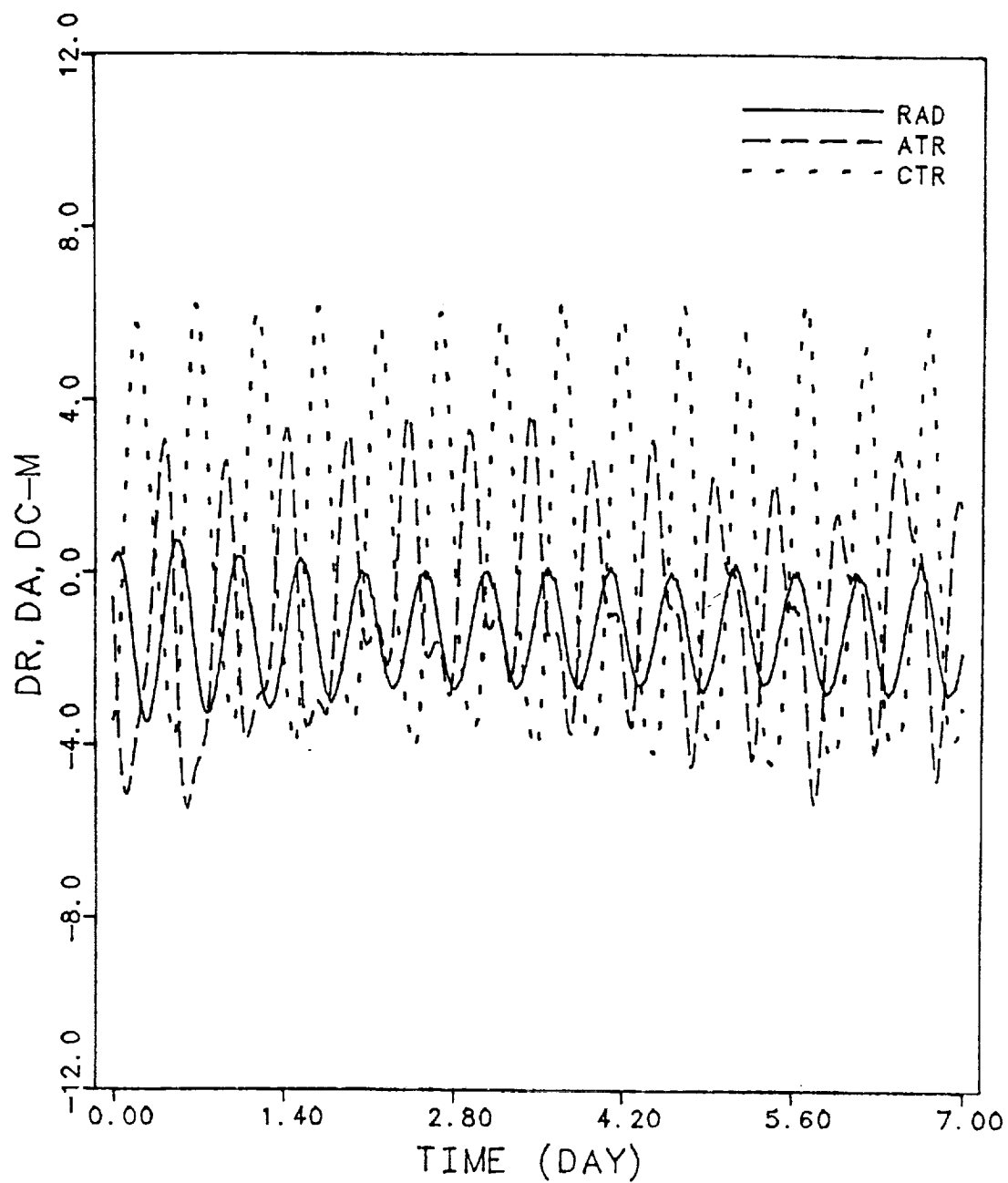
	3	6	9	11	12	13
	<u>MEAN(m)</u>					
Radial	-1.335	-1.348	-1.343	-1.316	-1.264	-1.313
A-Track	-1.898	-0.272	-0.801	1.037	-2.153	0.451
C-Track	0.482	0.487	0.452	0.049	-0.143	-0.158

	<u>RMS(m)</u>					
Radial	1.618	1.571	1.721	1.421	1.317	1.405
A-Track	3.133	2.228	2.442	1.752	2.777	1.475
C-Track	4.633	4.187	3.568	2.489	3.795	2.376

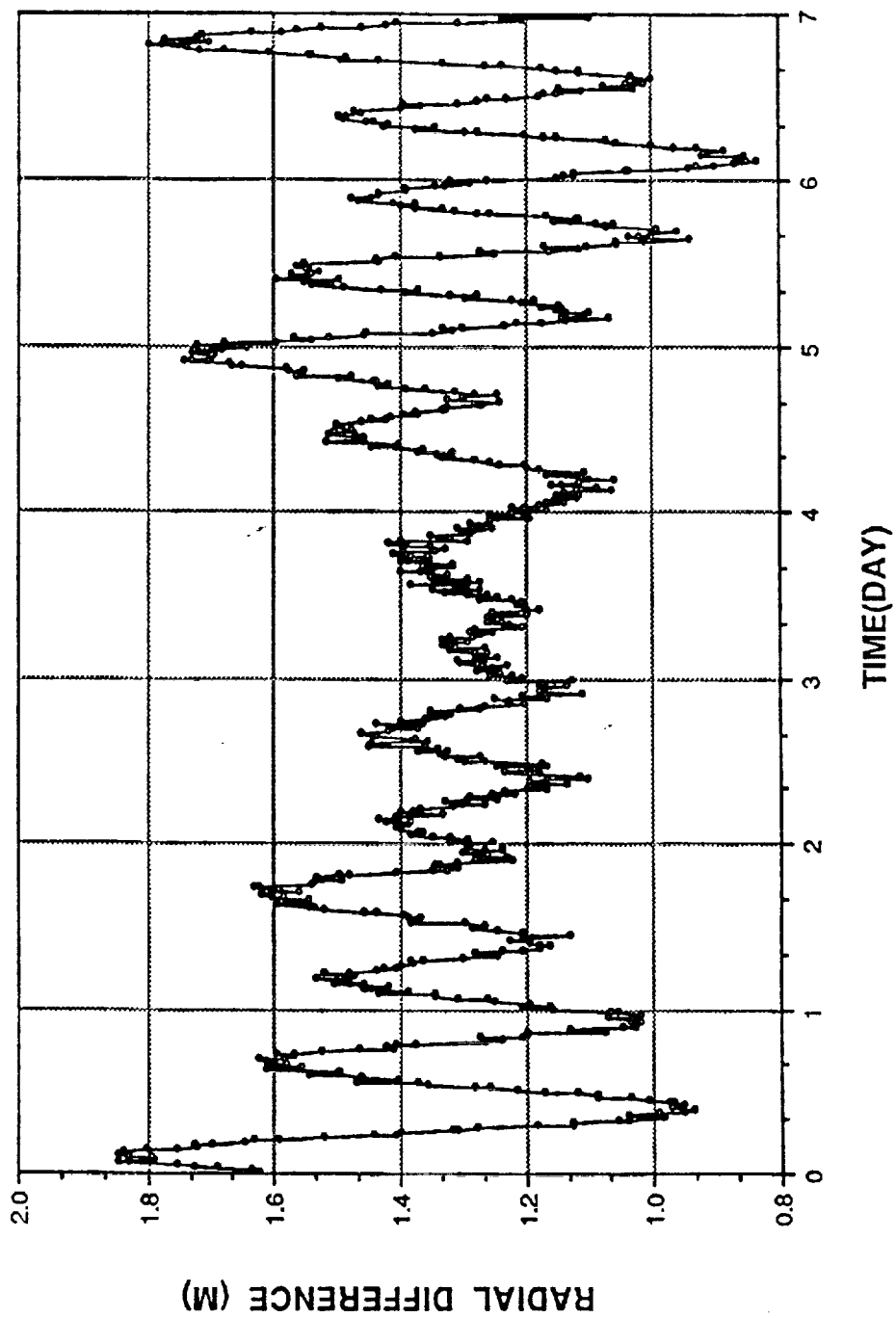
ECFEPH DIF(CSR-NSWC) SV PRN- 3
W499:CSR DD SOLN (15+3)GS:GLB499S. EST



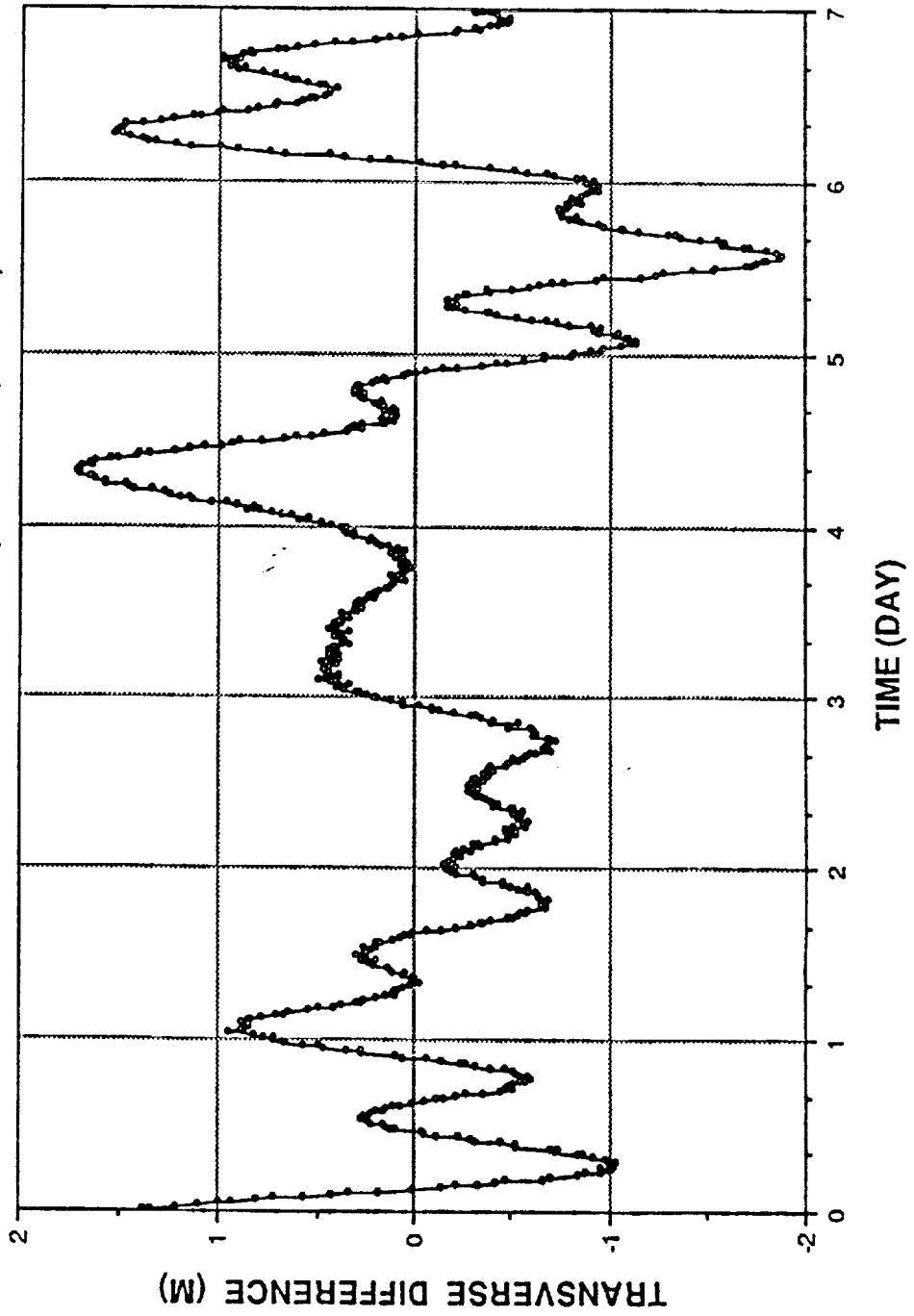
ECFEPH DIF(CSR-NSWC) SV PRN- 9
W499:CSR DD SOLN (15+3)GS:GLB499S. EST



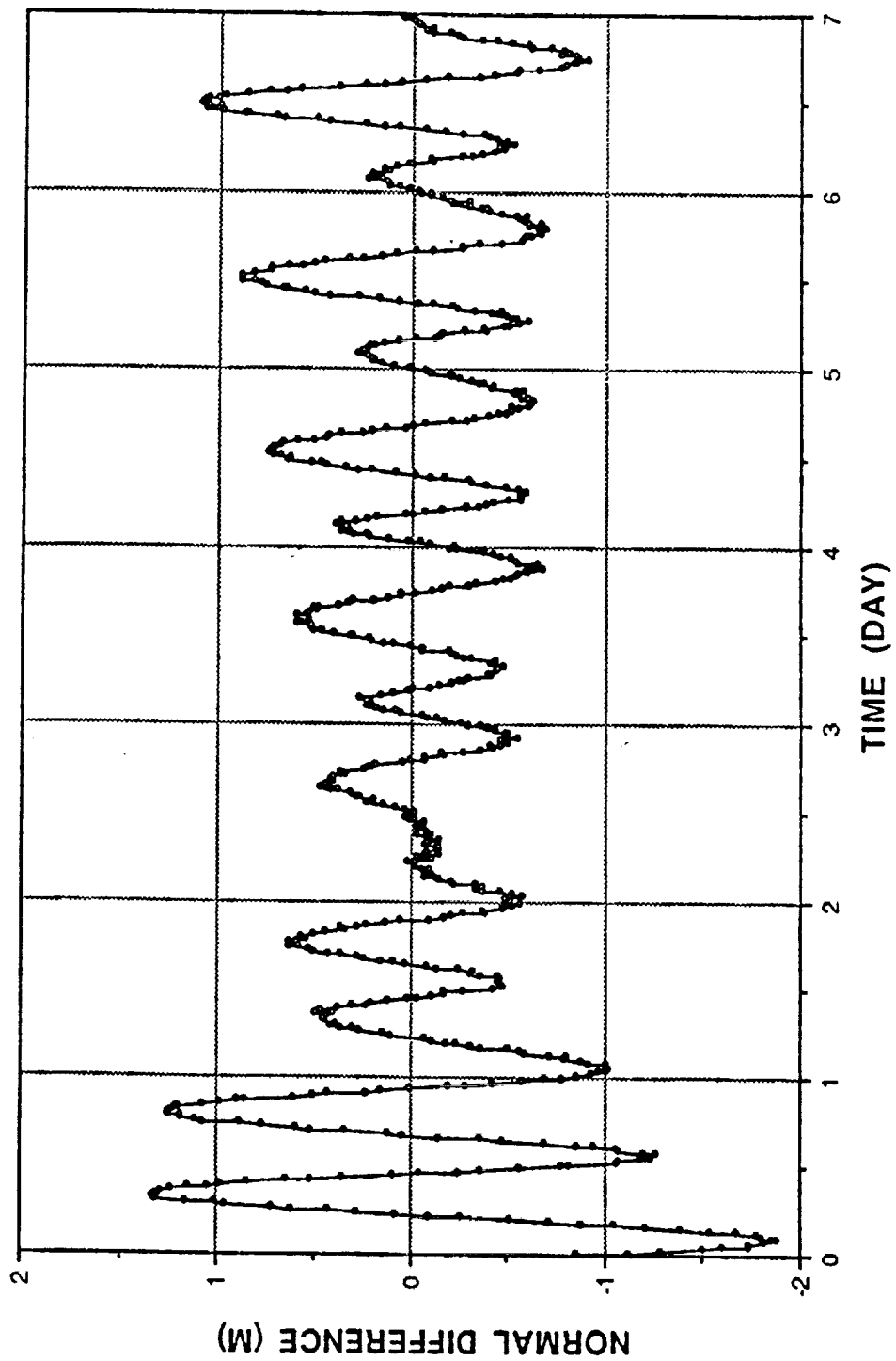
NSWC/UTCSR TRAJECTORY FIT (FOR SV#3, WK499)



NSWC/UTCSR TRAJECTORY FIT (FOR SV#3,WK499)



NSWC/UTCSR TRAJECTORY FIT (FOR SV#3,WK499)



GIG'91 Workshop

A g e n d a

Monday, 5 August 1991

Arrival of the participants

19.00 - 20.00 Open-air reception by good weather otherwise in the restaurant of the hotel

Tuesday, 6 August 1991

08.00 - 09.00 **Registration**

09.00 - 10.30 **Opening Session** (Chair: H. Seeger, IFAG)

Greeting and Remarks from Hosts: H. Seeger (IFAG)

Greeting and Remarks from IERS-Background and objectives of the IERS GPS Campaign: M. Feissel? (IGN)

Greeting and Remarks from the IERS GPS Technique Coordinator: W. Melbourne (JPL)

IERS Latest UTPM Results for the GIG Experiment Period: M. Feissel? (IGN)

10.30 - 11.00 Coffee break

11.00 - 12.30 **The Field Campaign** (Ch: W. Schlüter, IFAG/R. Neilan, JPL)

Summary of the Campaign-Planning, Standards, Procedures, Operations, Performance, etc: R. Neilan/S. Fisher (JPL)

Reports from Various Operations Teams (Representatives from organizations that participated in field ops will be asked to give a brief account of their experiences, insights, etc.)

12.30 - 14.00 Lunch

14.00 - 15.30 **The Field Campaign (cont.)**

Continued Reports from Ops Teams

Discussion: Lessons Learned, Recommendations for Future Campaigns (Standards, Procedures, Documentation, etc.)

15.30 - 16.00 Coffee break

16.00 - 18.00 **Data Analysis - I: Preparation**

Status of Data Pre-Processing & Distrib., Site Ties (S. Fisher)

Reports by Pre-Processing Centers (All)

Summary of Analysis Standards Proposed by JPL (G. Blewitt)

Discussion of above and related topics

19.00 Open-air grillparty

08.30 - 10.30 **Data Analysis - II: Results** - The plan is to organize this all-day session by topics. Those with results in several areas will therefore give several short presentations. The main topics are:

1. Descriptions of software and modeling strategies
2. Baseline Solutions
3. GPS Orbit Solutions
4. Earth Orientation Solutions
5. Geocenter Solutions
6. Discussion, Comparison & Analysis of Results

As of 25 July, the known groups planning to present results are:

U. Texas - B. Schutz

DGFI - K. Kaniuth

NSWC - E. Swift

UNAVCO - C. Rocken

MIT - R. King

JPL - Blewitt, Lichten, Lindqwister, Webb, YuncK

There is still space for more

10.30 - 11.00 Coffee break

11.00 - 12.30 **Data Analysis - II: Results (cont.)**
(See Above)

12.30 - 14.00 Lunch

14.00 - 15.30 **Data Analysis - II: Results (cont.)**
(See Above)

15.30 - 16.00 Coffee break

16.00 - 18.00 **Data Analysis - II: Results (cont.)**
(See Above)

19.30 Bus departure for wine-tasting

20.00 - 22.30 Wine-tasting in Ahrweiler

22.30 Busses return to hotel

Thursday, 8 August 1991

08.30 - 10.00 **Special Topics (Preliminary list):**

Multipath studies with GIG data (C. Rocken)

Do high latitude sites pose special problems? (TBD)

Implications of SA/AS for global GPS measurements (T. YuncK)

Status of 3CAR GPS geodesy project in Antarctica (J. Manning)

Summary of early GIG results (TBD)

10.00 - 10.30 Coffee break

10.30 - 12.30 **Open Discussion (Suggested topics):**

Implications of early GIG results

Establishing a GPS-based global reference frame Integrating GPS into IERS operations and products Plans for a follow-up GIG 91 workshop before IGS campaign?

12.30 Lunch

14.30 Sightseeing tour through the Ahr-Valley

ANALYSIS OF GIG 91

**B. Schutz, P. Abusali, M. Watkins,
H. Rim, and B. Tapley**

**Center for Space Research
The University of Texas at Austin**

**GIG Workshop
Ahrweiler, Germany
August 1991**

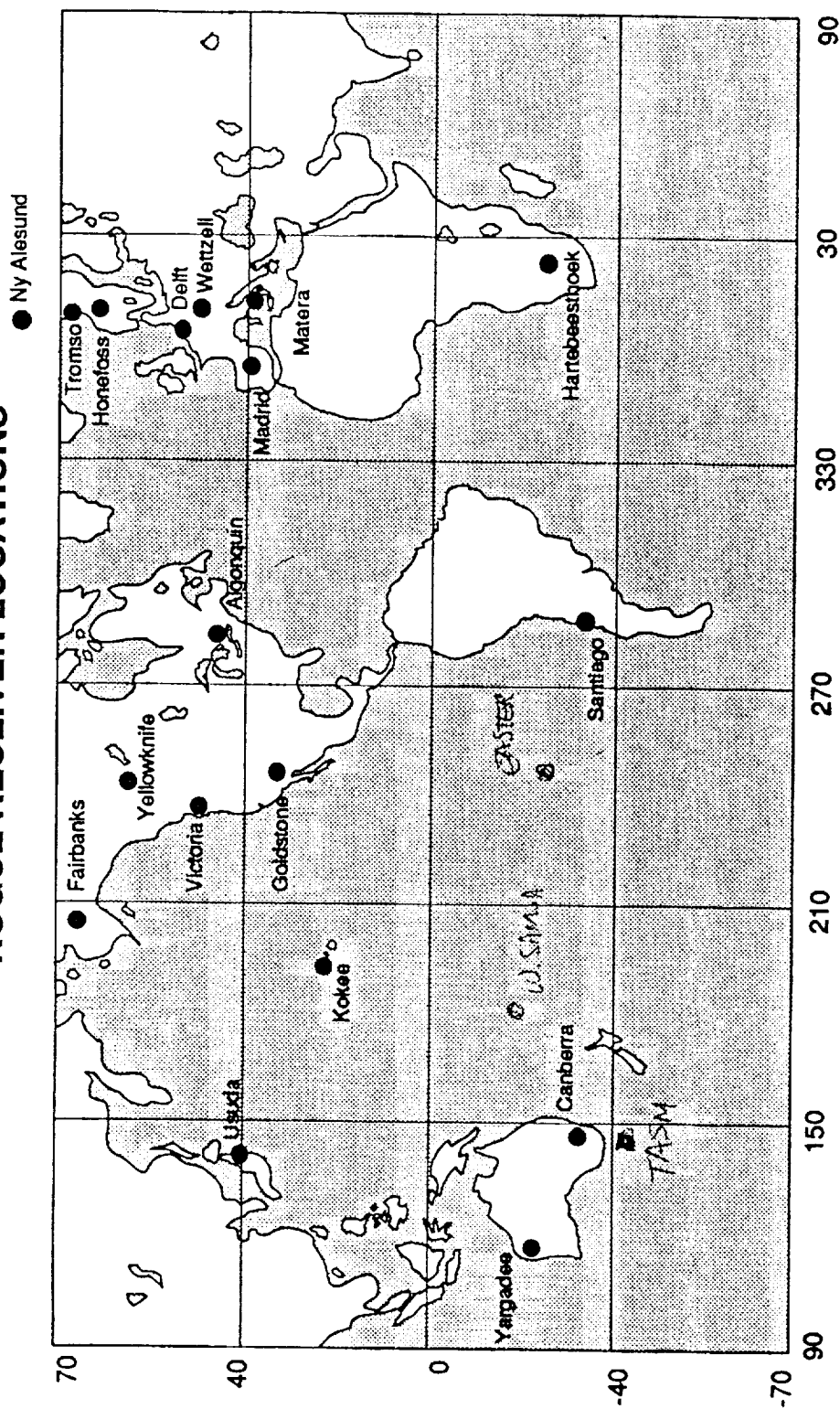
SUMMARY

- Analyzed days 34-38 of GIG '91
- Data: 17 Rogue Sites
Plus Hobart mini-mac
W. Samoa TI
Easter I. TI
- Analysis Strategies
 - Fix Hobart Kokee and Wettzell to SV5
 - No a priori constraints on estimated parameters
 - Estimated baselines range from 800 km to 8000 km
 - Repeatability result: 20 PPB to 2 PPB
 - Adjust all stations with 1 meter a priori, all other estimated parameters have no a priori
 - Pole position error estimate (RMS): 1 mas

GIG 91 DATA

- All Rogue sites, except S. California array and Honefoss
- Augmented network
 - Hobart, Tasmania (Mini-Mac)
 - W. Samoa (TI-4100)
 - Easter Island (TI-4100)

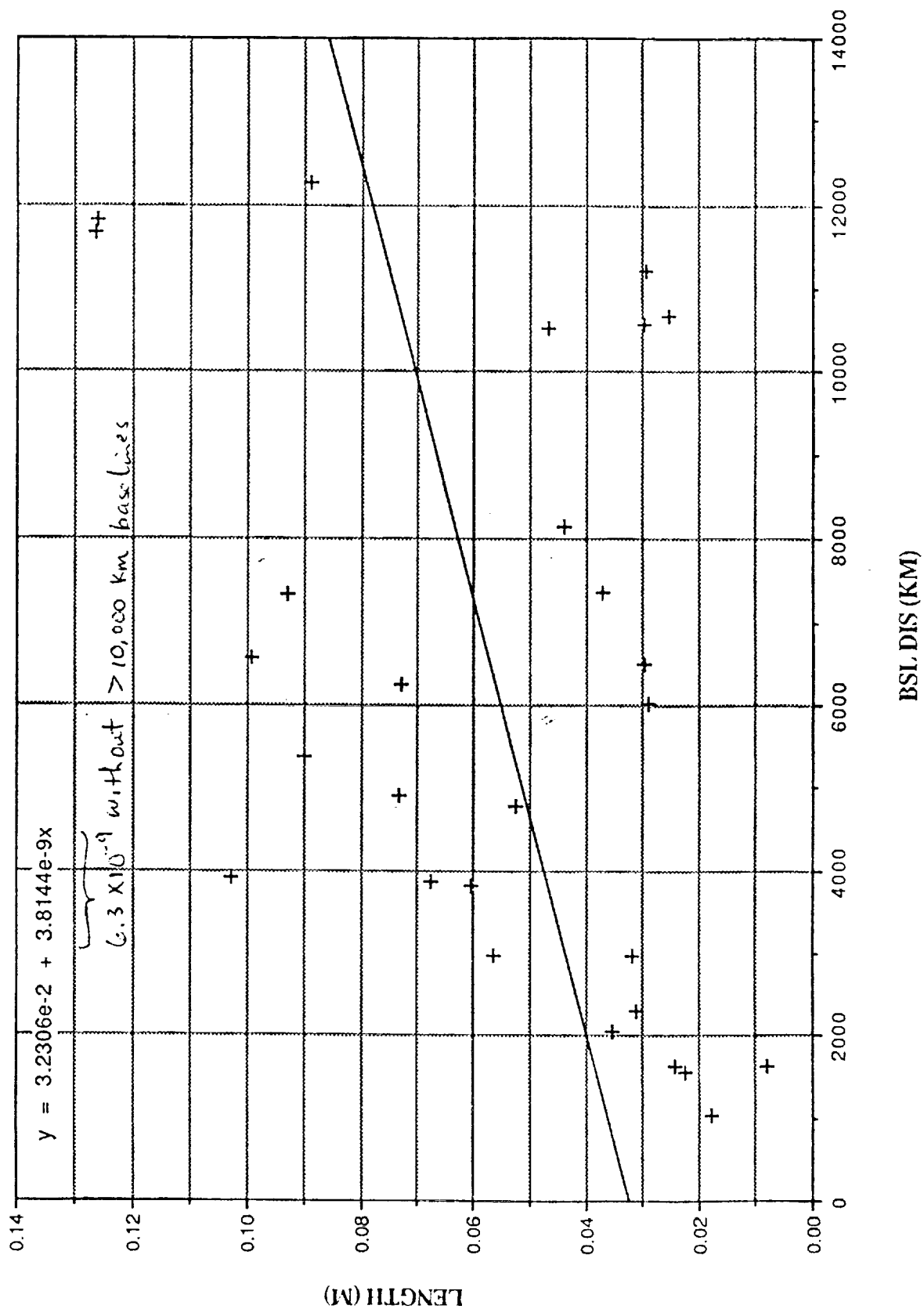
GIG '91 GPS Experiment for IERS and Geodynamics ROGUE RECEIVER LOCATIONS



ADDITIONAL ROGUES IN CALIFORNIA PERMANENT ARRAY:
PINON, SCRIPPS, JPL MESA

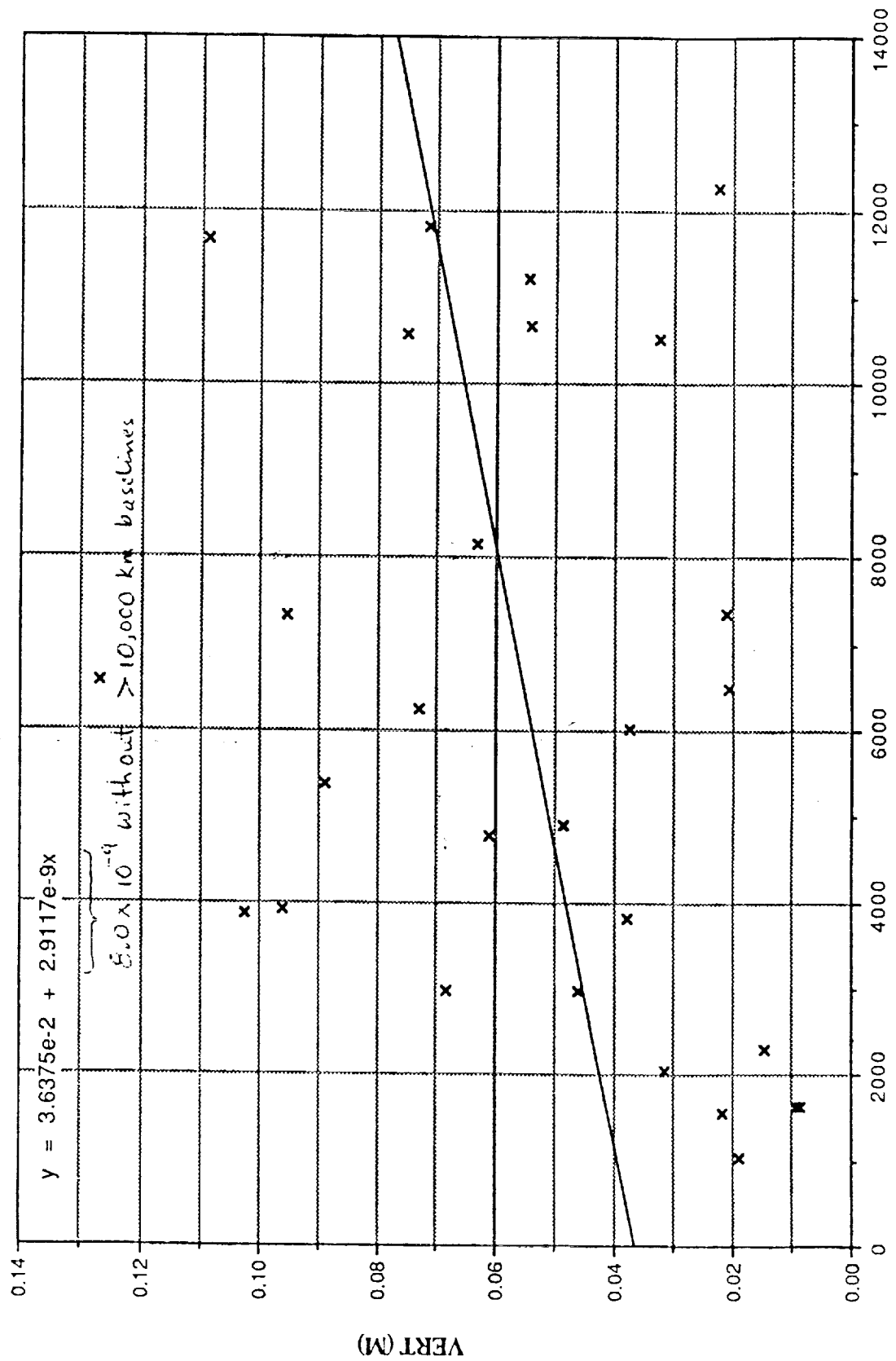
REPEATABILITY BASED ON 4 DAYS 8 STA, 28 BASELINES

+ LENGTH (M)

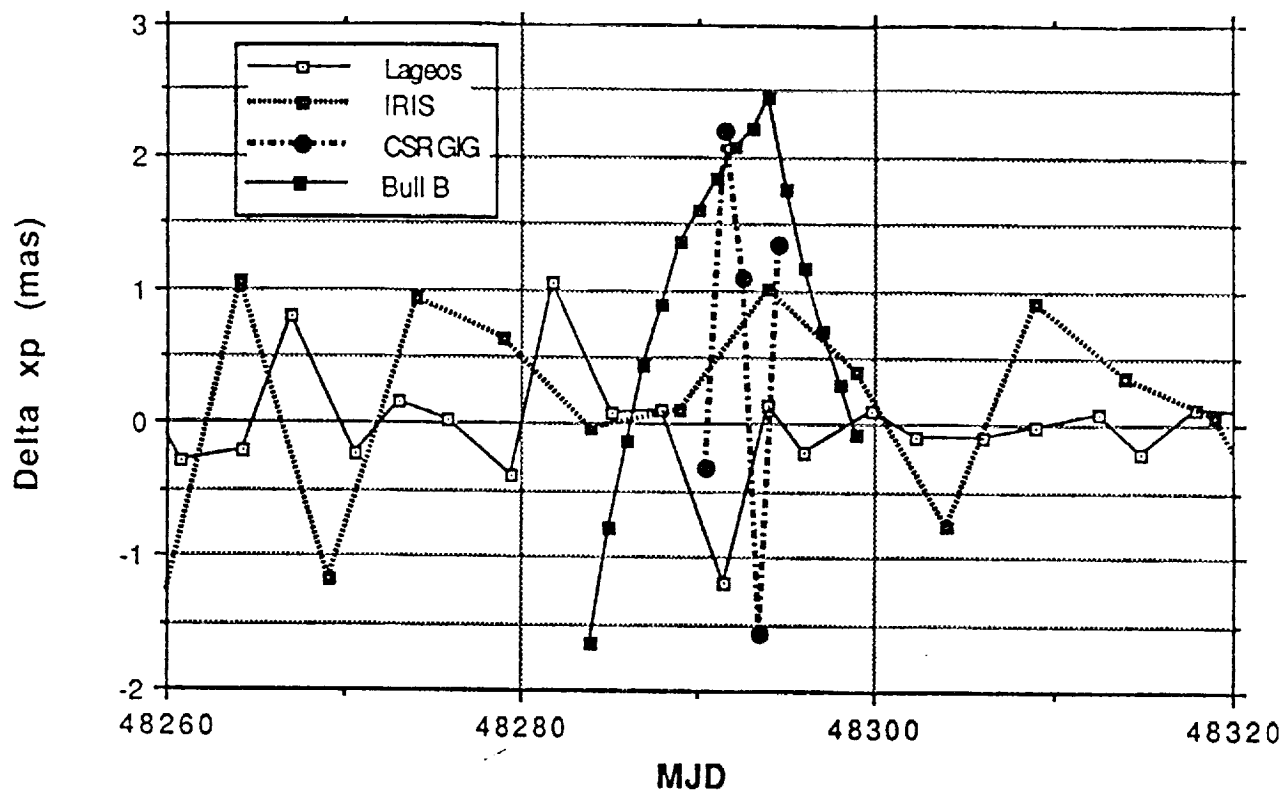


REPEATABILITY BASED ON 4 DAYS 8 STA, 28 BASELINES

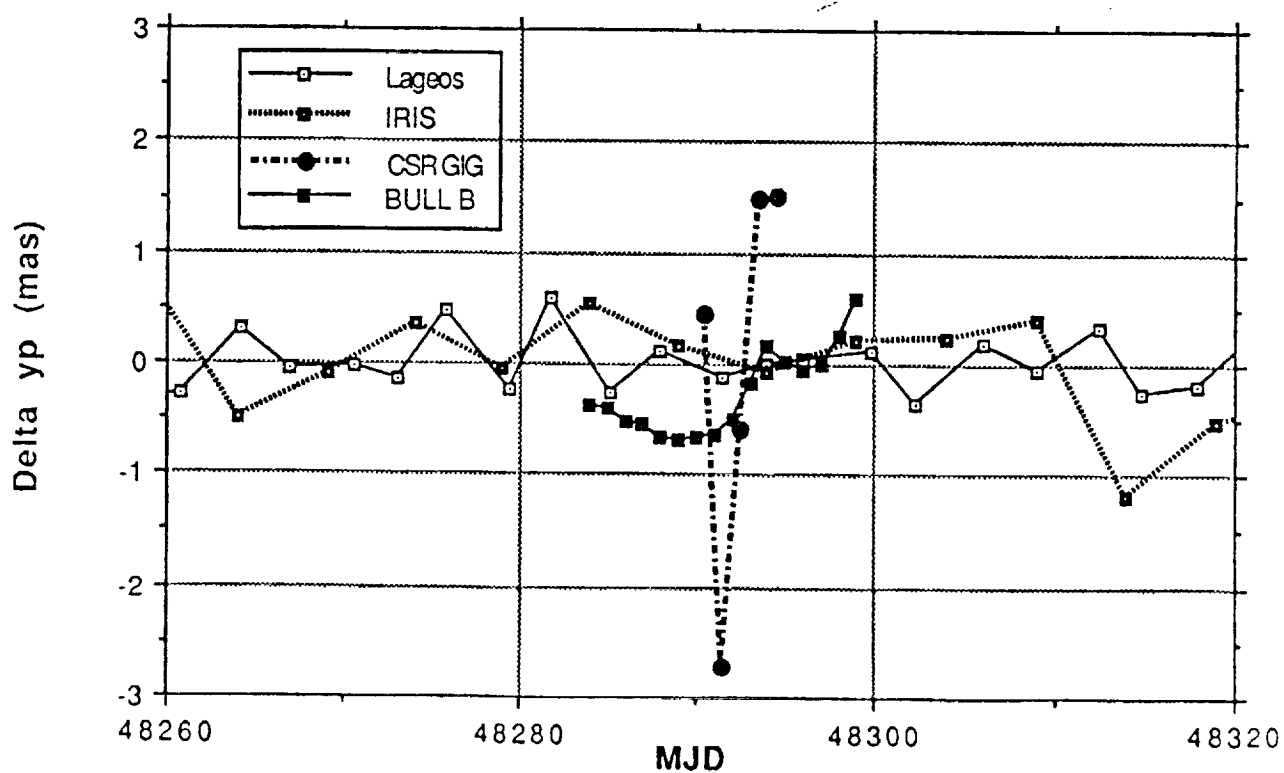
x VERT (M)



Polar Motion Comparison During the GIG Campaign



Polar Motion Comparison During the GIG Campaign



GLOBAL GPS ORBIT DETERMINATION

**B. Schutz, P. Abusali, M. Watkins,
H. Rim, and B. Tapley**

**Center for Space Research
The University of Texas at Austin**

**IAG
Vienna, Austria
August 1991**

SUMMARY

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 - Repeatability result: 20 PPB to 2 PPB
 - Adjust all stations with 1 meter a priori, all other estimated parameters have no a priori
 - Pole position error estimate (RMS): 1 mas

SOFTWARE VALIDATION

- **Force and Kinematic Models**
 - MSODP and MSODP1: Agree to sub-mm level over 7-day GPS arcs
 - MSODP1 and UTOPIA: Agree to mm level in all models (ROCK4 not tested, not available in UTOPIA)
 - UTOPIA and GEODYN (GSFC): Agree to mm level for TOPEX/POSEIDON (largest difference in ocean tide force model)
 - UTOPIA extensively used for SLR processing
 - Etalon analysis/models similar to GPS
(fit 800 days of SLR Etalon data to few cm)

SOFTWARE VALIDATION (continued)

- **GPS Measurement Model**
 - Tests preprocessing system
 - Zero baseline tests of TI and Trimble
 - Short, calibrated baseline tests between Trimble, TI, TI-Trimble, TI-Minimac, and Trimble-Minimac
 - Comparisons of GPS results with VLBI and SLR
(Recent: Onsala/Tromsø, McDonald/Platteville/Quincy; results 1–2 parts in 10^8)

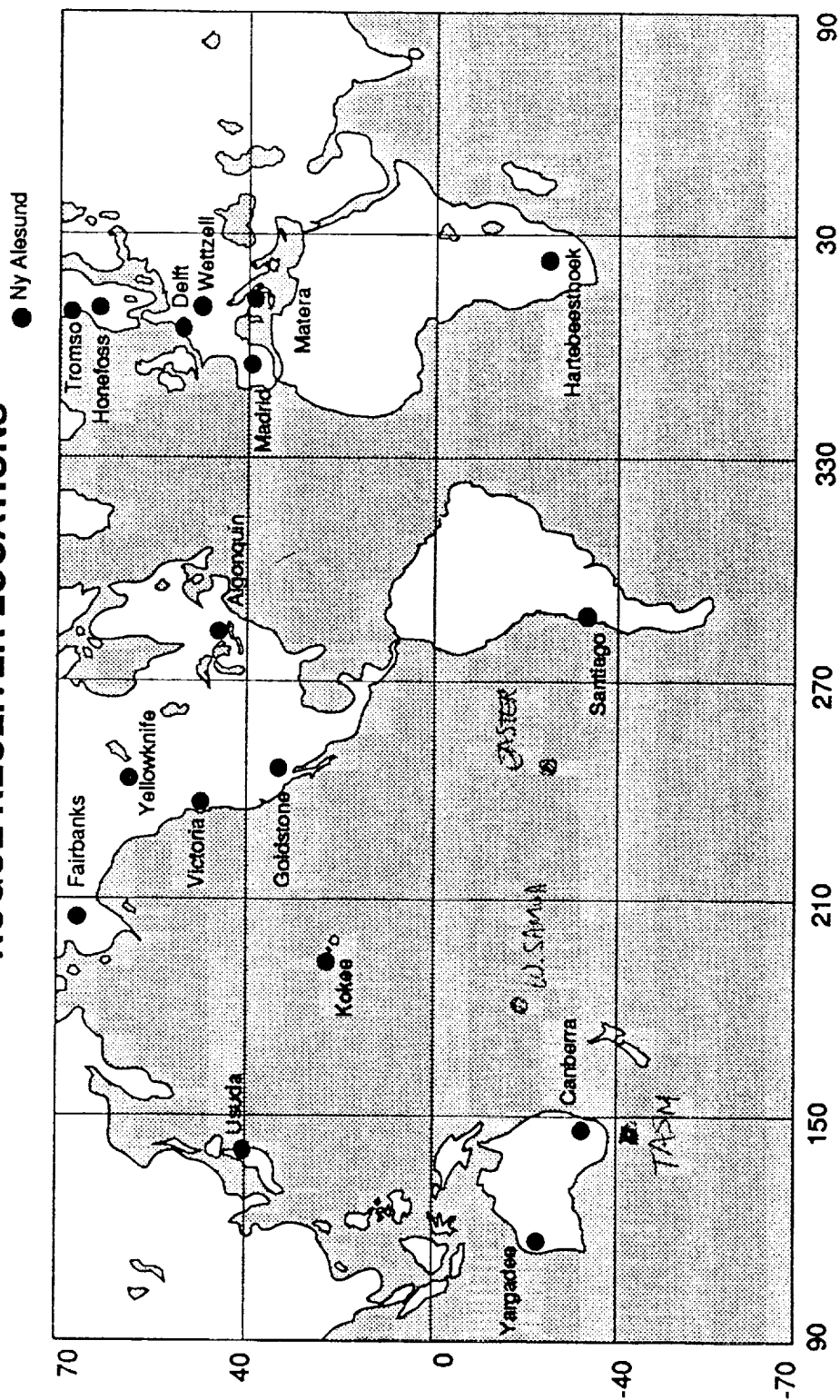
GEODETIC PROCESSING (COMPUTER: CRAY Y-MP)

- MSODP: Multi-Satellite Orbit Determination Program. Developed for GPS processing (planned to be phased out by end of 1991).
- MSODP1: Similar to MSODP, but includes high (GPS) and low (e.g., TOPEX) satellites. Will become primary processing software for multi-satellite data. Has more extensive force models, more compatible with UTOPIA, write regress files, etc.
- LLISS: Large Linear System Solver. Uses regress file (used for gravity estimation, etc.).

DATA PREPROCESSING (COMPUTER: VAX)

- Convert raw receiver binary or RINEX into VAX binary
- Review and correct receiver phase measurement time tags (EDORBCL)
- Insert information flags (PREPB)
- Edit phase, fix cycle slips (EDPH)
- Review double difference, perform further editing, write DD file (ASCII) (also preliminary geodetic analysis
- Utility programs (print binary file, edit binary flags, sample data, etc.)

GIG '91 GPS Experiment for IERS and Geodynamics ROGUE RECEIVER LOCATIONS



ADDITIONAL ROGUES IN CALIFORNIA PERMANENT ARRAY:
PINON, SCRIPPS, JPL MESA

GIG 91 DATA

- All Rogue sites, except S. California array and Honefoss
- Augmented network
 - Hobart, Tasmania (Mini-Mac)
 - W. Samoa (TI-4100)
 - Easter Island (TI-4100)

ANALYSIS

<u>DAY</u>	<u>STATUS</u>
34	✓
35	✓
36	✓
37	✓
38	✓
39	
TEST	
DATA	
SET	
42	
43	
44	

DOUBLE DIFFERENCE COVERAGE
OVER 24 HOUR PERIOD
DAY 36

PRN

23

22

21

20

19

18

17

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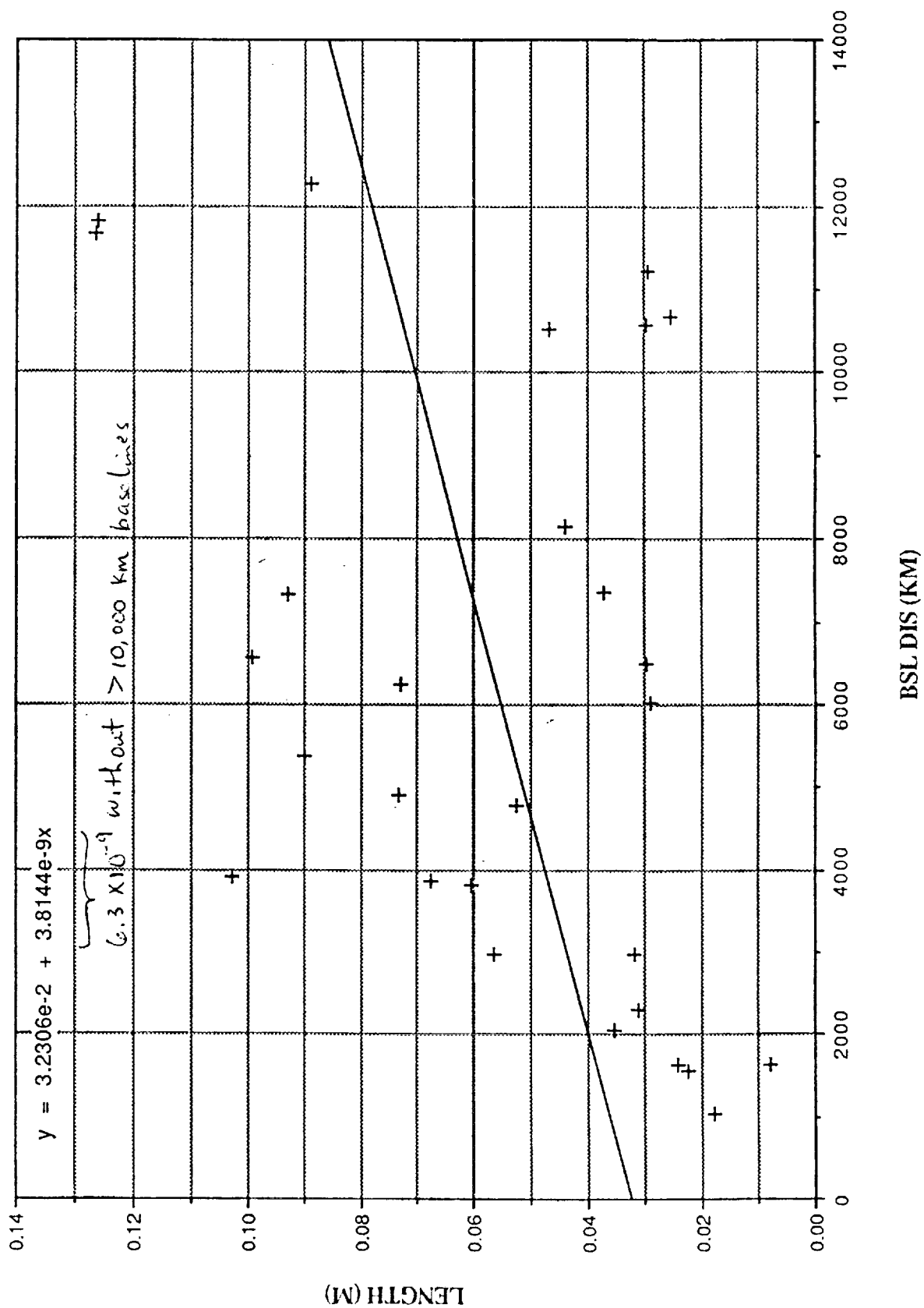
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GPS ANALYSIS MODELS

MSODP1/LLISS	MSODP
<ul style="list-style-type: none"> • Gravitational Model • $GM = 398600.4404 \text{ km}^3/\text{s}^2$ • Nominal field: TEG-2 (Tapley, et al.) • Truncation of field: 8×8 • Point mass Sun and Moon • Solid Tide: degree 2 • Ocean Tide: Not included • Central body relativistic perturbation 	398600.436 GEM-T1 Same Same Same Same Same
<ul style="list-style-type: none"> • Nongravitational Model • Solar Radiation (ROCK4) • y-bias • Earth Radiation: Not included • Empirical Forces: <ul style="list-style-type: none"> • Along track (CT) • Radial (once/rev) • Normal (once/rev) 	Same Same Same No No No

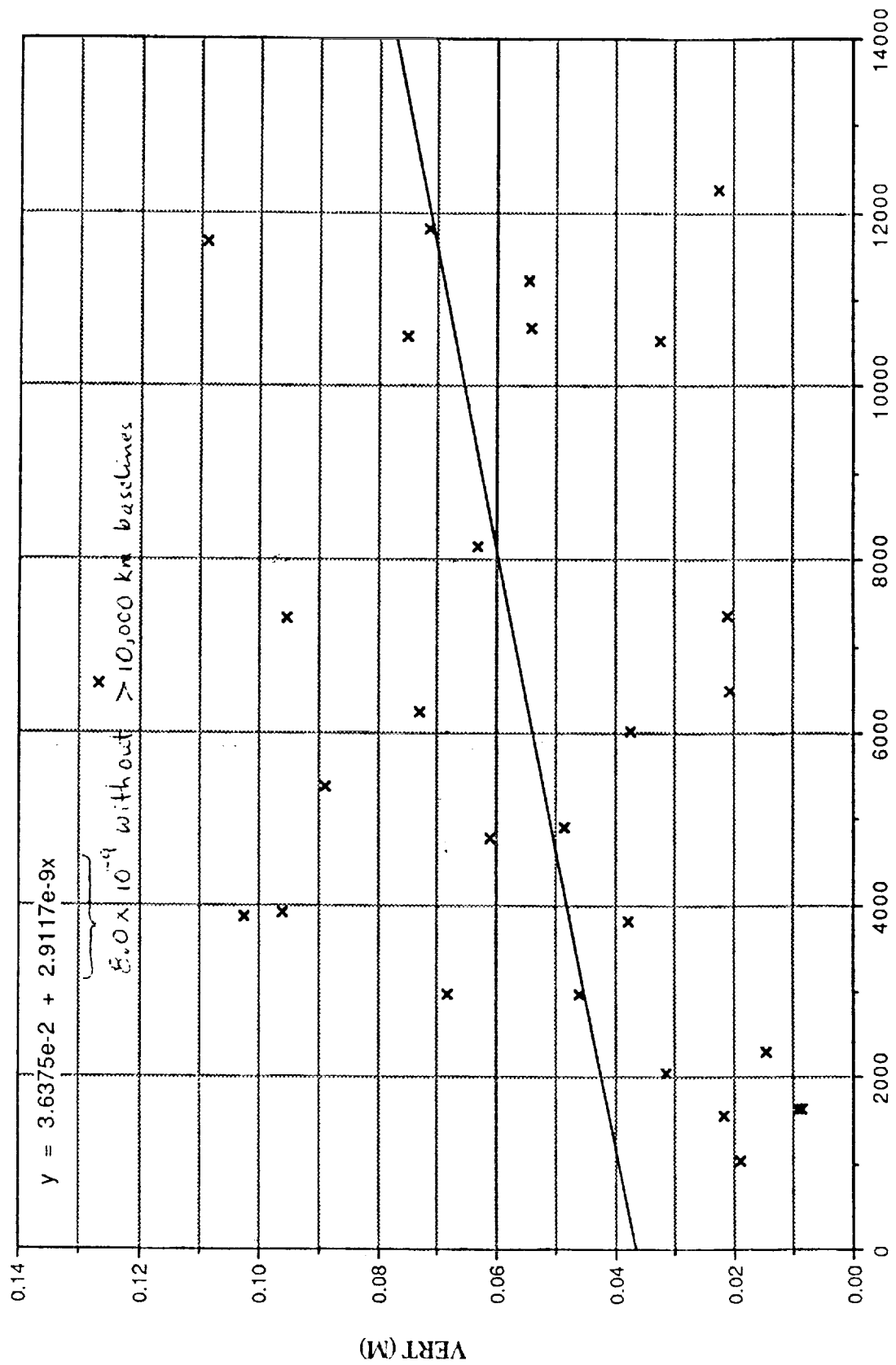
REPEATABILITY BASED ON 4 DAYS 8 STA, 28 BASELINES

+ LENGTH (M)



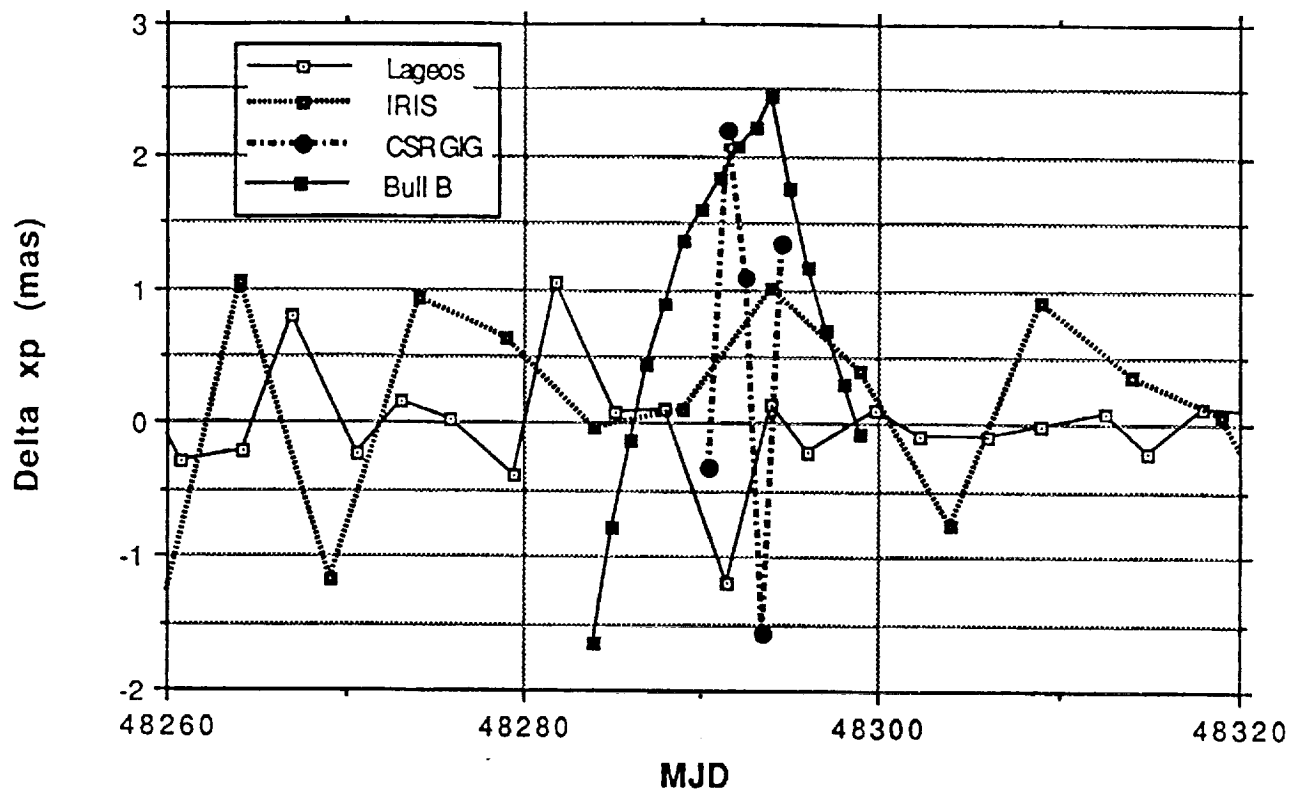
REPEATABILITY BASED ON 4 DAYS 8 STA, 28 BASELINES

x VERT (M)

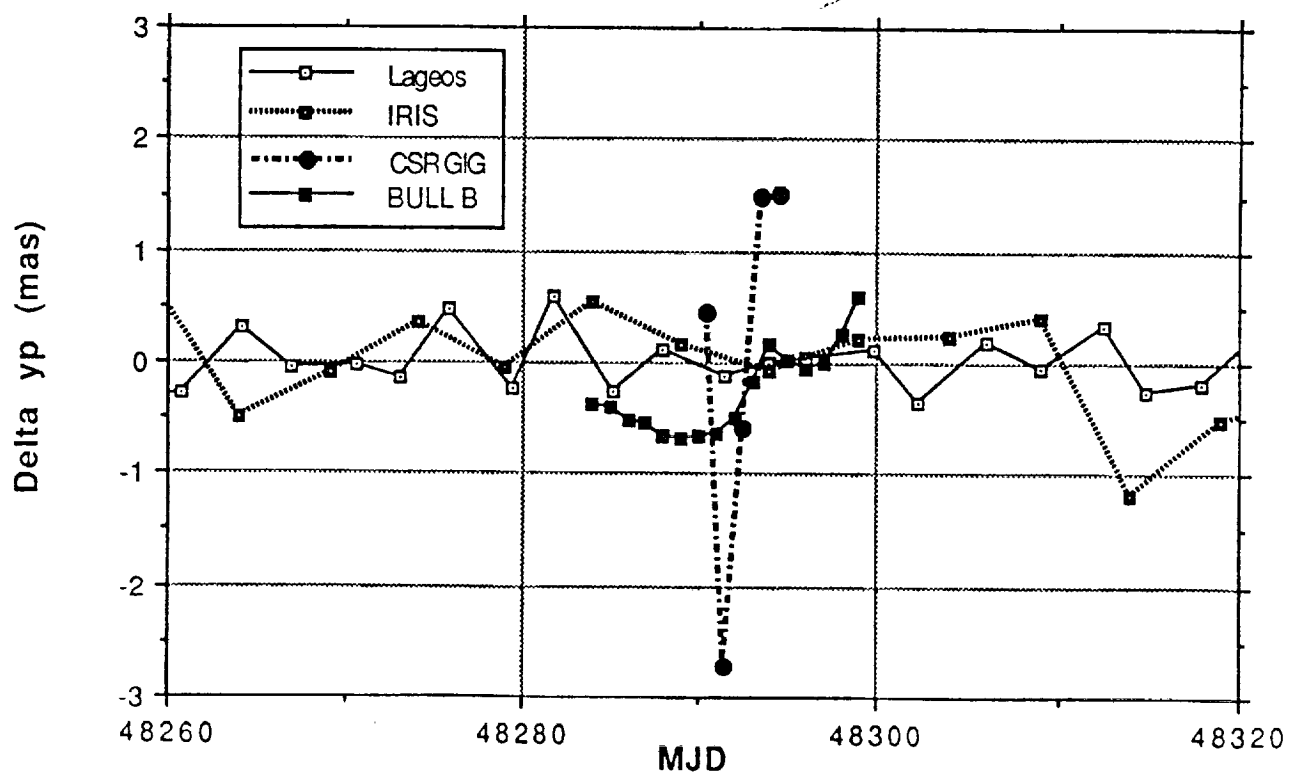


BSL DIS (KM)

Polar Motion Comparison During the GIG Campaign



Polar Motion Comparison During the GIG Campaign



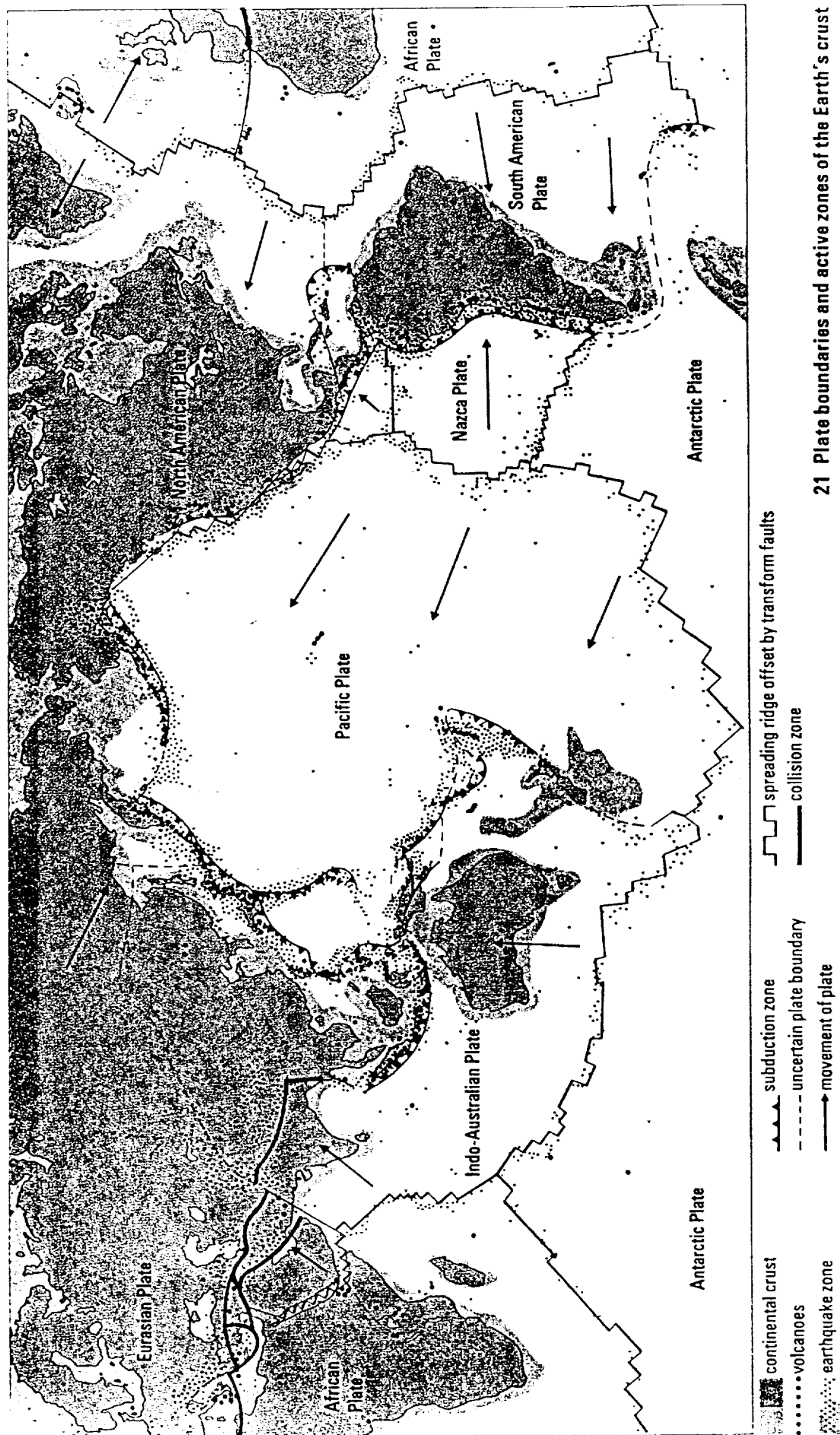
GEODETIC ANALYSIS OF GPS MEASUREMENTS NEAR THE TONGA TRENCH: 1988-1990

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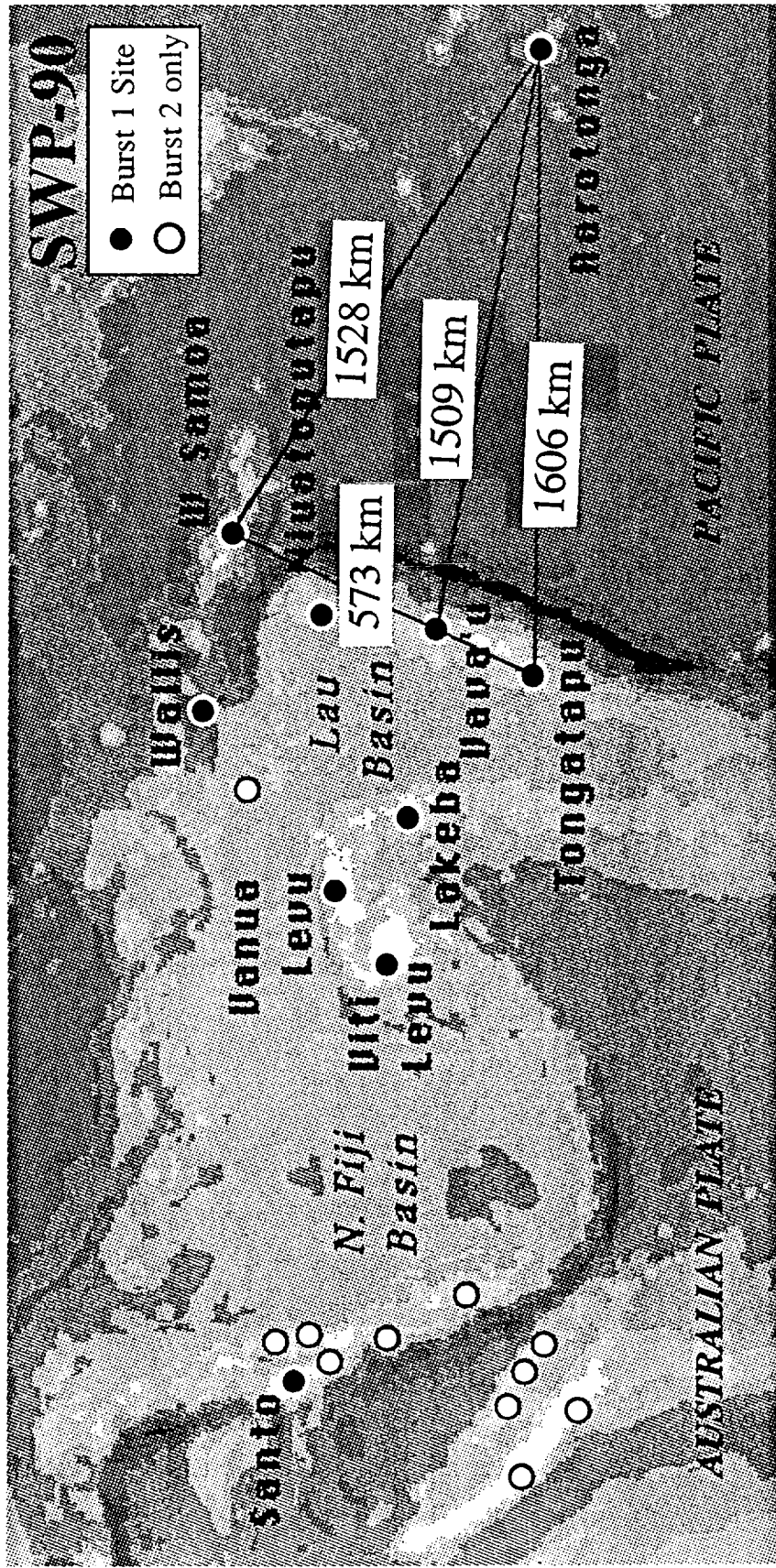
DECEMBER 1991
SAN FRANCISCO



21 Plate boundaries and active zones of the Earth's crust

SWP-90

- Burst 1 Site
- Burst 2 only



SOUTHWEST PACIFIC DATA CHARACTERISTICS

- 1988:

Fiducial: TI-4100 (8 sites), Mini-Mac (1 site)

SWP Network: TI-4100 (4 sites)

SA off, 11 day campaign, 7 satellites

- 1989 (Session 1):

Fiducial: Mini-Mac (5 sites), TI-4100 (10 sites)

SWP Network: TI-4100 (5 sites), Trimble SLD (3 sites)

SA off, 5 day campaign, 7 satellites

- 1990 (Burst 1):

Fiducial: Mini-Mac (6 sites), Trimble SST(5), TI-4100 (4), Rogue (5)

SWP Network: Trimble SST (11 sites)

North American Evaluation Network: Trimble SST & TI-4100 (3 sites)

SA on, 8 day campaign, 13 satellites

SOUTHWEST PACIFIC PROCESSING STATUS

- 1988:
Processing complete (11 days); various experiments in progress
- 1989 (Session 1):
Processing in progress; processing of Sessions 2-4 completed to establish DMA Smithfield coordinates in reference frame
- 1990 (Burst 1):
Processing complete (except DMA data); various experiments in progress

GPS ANALYSIS MODELS

MSODP Force Models

- Gravitational Model
 - $GM = 398600.440 \text{ km}^3/\text{s}^2$
 - Nominal field: GEM-T1
 - Truncation of field: 8×8
 - Point mass Sun and Moon
 - Solid Tide: degree 2
 - Ocean Tide: Not included
 - Central body relativistic perturbation
- Nongravitational Model
 - Solar Radiation (ROCK4)*
 - y-bias*
 - Earth Radiation: Not included

* Denotes solve-for parameter

MSODP Reference Frame

- Fixed station coordinates
 - Combined SLR/VLBI
 - SLR: CSR91L03
 - VLBI: GSFC GLB718
 - Epoch: January 1988
 - Coordinates mapped to campaign epoch using SLR or VLBI observed velocities
- IERS Standards:
 - Precession/nutation
 - Solid tides/ocean loading
 - Earth Rotation
 - Lageos pole position (x,y)
 - Lageos/VLBI UT1

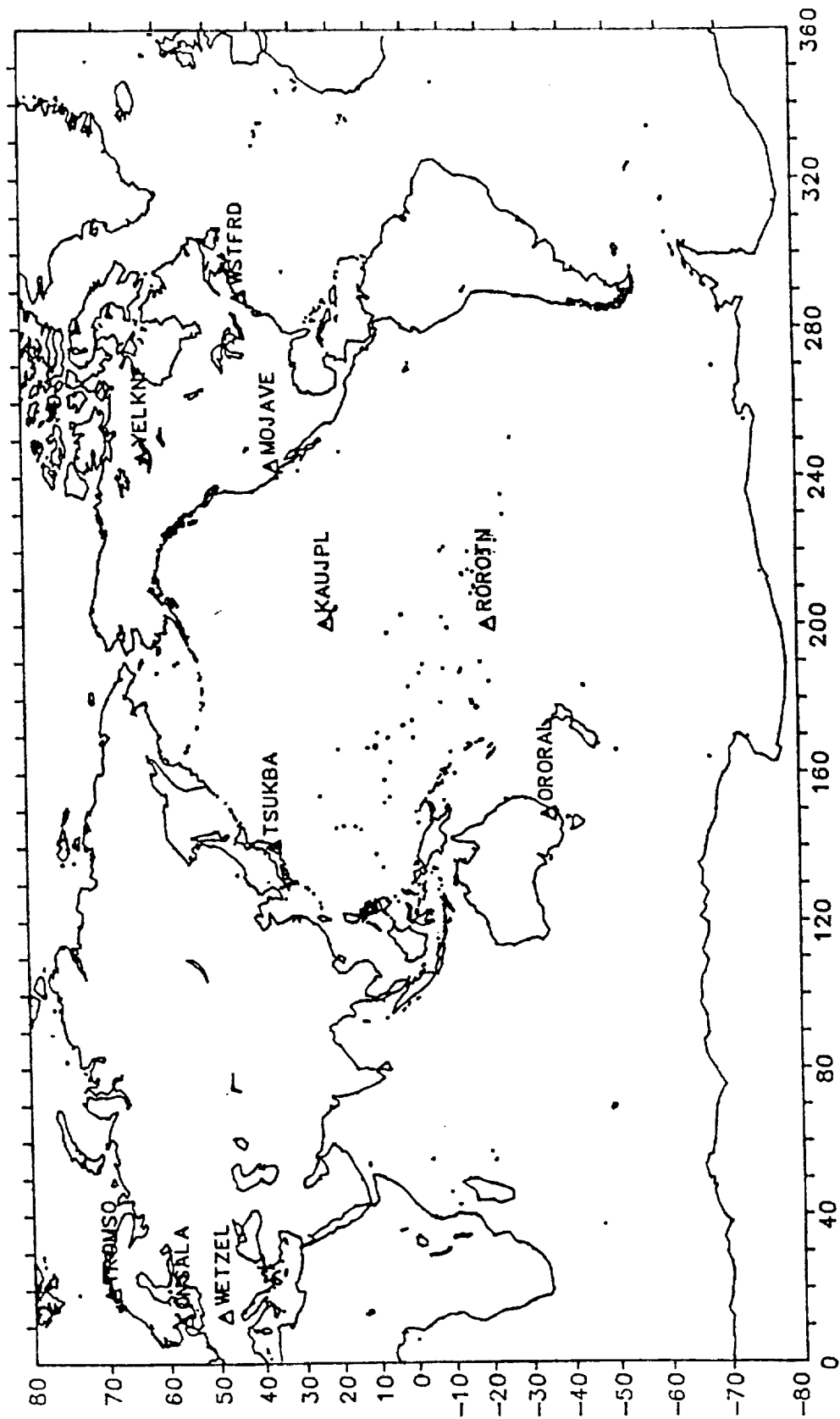


Figure 2. 1988 Southwest Pacific Campaign Global Sites

SWP-90 ANALYSIS STRATEGY AND EXPERIMENTS

- Global fiducial network to determine orbits
- Multi-day (7 day) arcs
- Simultaneous adjustment of orbit parameters (including force model parameter), 2.5 hour zenith delay, ambiguity parameters, station coordinates; all estimated parameters have infinite a priori covariance
- Experiments:
 - Full global network solution (selected fixed sites)

Number of Double Differences (DD): ~ 326,000
DD RMS: 2.5 cm

- Reduced network solution: emulate the network configuration in 1988

Number of Double Differences (DD): ~ 154,000
DD RMS: 2.9 cm

SWP-90 SOLUTIONS

- Full global network fixed sites:
Minimac: Mojave, Westford, Richmond, Wettzell, Tasmania
- Reduced network fixed sites:
Mojave, Westford, Wettzell, Orroral (Trimble)
- Comparison between full network and reduced network:

Baseline	Global (m)	Reduced (m)
Rarotonga/Vava'u (1509180+)	0.7633 (.025)	0.7724 (.026)
Rarotonga/Tongatapu(1605587+)	0.9078 (.025)	0.9206 (.027)
Rarotonga/W.Samoa(1527538+)	0.6459 (.017)	0.6574 (.018)

(Repeatability RMS in parentheses)

- Precision estimate:
 - From above 3 lines: 10-20 parts per billion
 - From 103 lines in the global network: 2.3 cm + 8 ppb*length

SWP-90 EVALUATION SOLUTIONS

- Based on results from full global network:

Baseline	SWP-90	SLR/VLBI
Orroral (Tr)/Tasmania (MM) (805722+)	0.200	0.214
Kokee Park (Tr)/Huahine (Tr) (4312837+)	0.388	0.333
Mojave (MM)/McDonald Obs.(Tr) (1305503+)	0.619	0.625
Wettzell (MM)/Onsala (TI) (919659+)	0.478	0.449

(All distances in meters)

- Accuracy estimate: 10-30 parts per billion
 - Receiver mix used in evaluation
 - Evaluation sites include mix of SLR and VLBI

SWP-88 SOLUTIONS

- Fiducial sites (all TI-4100):
Orroral, Kokee Park, Mojave, Westford, Richmond, Yellowknife, Wettzell,
Onsala, Tromso
- Fixed sites:
Orroral, Mojave, Westford, Wettzell
- Strategy:
 - Multi-day arcs: separate arcs for GPS Week 444 and Week 445 (July 1988)
 - Simultaneous adjustment of orbit and geodetic parameters (as in 1990)
- Solution characteristics:
 - Week 444: 73710 DD, RMS = 2.3 cm
 - Week 445: 43147 DD, RMS = 2.1 cm
 - Repeatabilities (combined 444 and 445):
 - Rarotonga/Tongatapu: 4.6 cm
 - Rarotonga/Vava'u: 4.1 cm
 - Rarotonga/W. Samoa: 6.9 cm

CONCLUSIONS

- SWP-90:
 - Solution has precision at level of 10 to 20 ppb
 - Comparison with SLR/VLBI baselines in Australia, French Polynesia, North America and Europe indicates agreement at the 10-20 ppb level
 - Results from global network of 20 sites compared with results of a reduced network to emulate 1988 fiducial configuration: agreement within precision estimate
- SWP-88:
 - Solution based on 7 Block I satellites, TI-4100 receivers (maximum 4 satellites)
 - Experiments using two separately edited data sets from Week 444 show differences at the repeatability level
 - 1988 results exhibit higher daily repeatability than 1990 (~ 4.5 cm vs. ~2.5 cm)
 - Comparison with VLBI baseline Wettzell/Tromso shows agreement at 10 ppb (Baseline: 2296 km)
- SWP-89:
 - In progress